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Peat Resources and Glacial Geology of Chapman Swamp and Adjacent Area Westerly, Rhode Island

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PEAT RESOURCES AND GLACIAL GEOLOGY

OF

CHAPMAN SWAMP AND ADJACENT AREA

WESTERLY, RHODE ISLAND

BY

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ABSTRACT

Chapman Swamp is a 685 ha freshwater wetland complex in Westerly, Rhode Island. Seventy percent of the wetland area is forested, 17.9% is scrub-shrub, 7.0% is aquatic bed and 1.3% is emergent.

The peat stratigraphy in the wetland is composed of wood, reed-sedge and moss peats. Wood peat is typically low ash, reed-sedge peat is variable in ash content depending on proximity to a fluvial sediment source and moss peat is high-ash in basal sections due to contamination from eolian sources in the early Holocene. The most common stratigraphic relationship is wood peat overlying moss or reed-sedge peat. The maximum and average peat thicknesses in the wetland are 325 cm and 160 cm, respectively. The wetland basin contains 10,731,000 cubic meters of peat, 6,053,000 cubic meters (1,203,180 tonnes, air dry) of which is fuel-grade. Fuel-grade wood peat has the highest mean calorific value (6401 BTU/lb, air dry), reed-sedge is second (6024 BTU/lb, air dry) and moss is lowest (5691 BTU/lb, air dry).

The area of the resource with the highest energy potential could supply the fuel to produce more than 20% of the town of Westerly's electricity for 45 years or heat 1000 homes heated by wood stoves for 50 years.

The Chapman Swamp basin is a remnant of a shallow ice-marginal lake that existed during late Woodfordian deglaciation of Rhode Island. Primary sedimentary

structures observed in deposits around the margin of the basin and from a vibracore near the margin are characteristic of delta-plain, delta-front, pro-delta slope and lake-bottom depositional environments of a kame-delta depositional system. Initially lake drainage was to the southwest along the north side of the Charlestown Moraine. Ice retreat allowed drainage to the north through the Pawcatuck River valley, lowering lake level to expose divides which separated the lake into several small basins. Hydrophytes became established and peat accumulation began.

The association of this wetland with a former glacial lake basin is one part of a continuum of relationships between peat and glacial environments in southern New England.

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INTRODUCTION

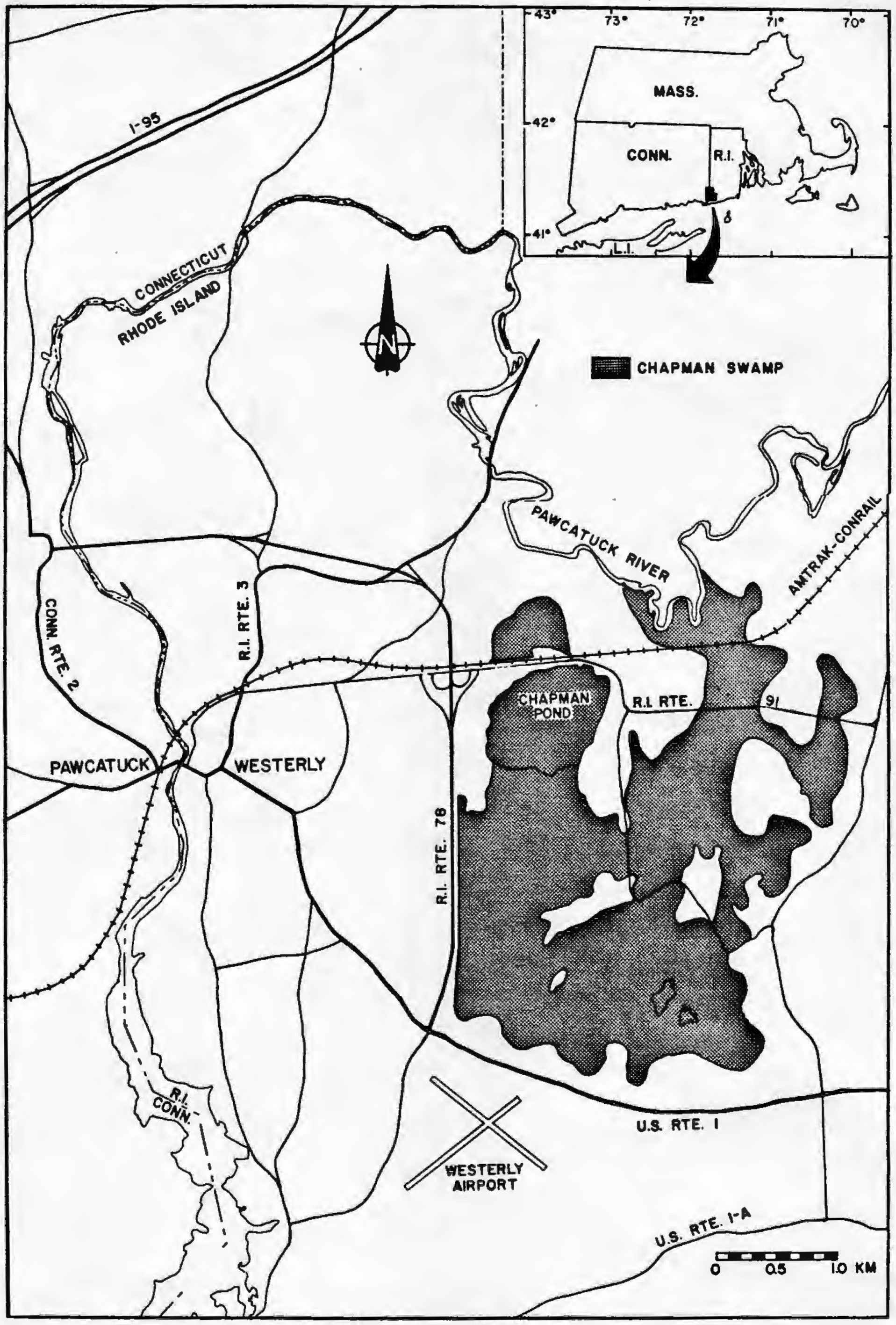
In recent years the dependence of the United States on foreign energy resources has become increasingly evident. In 1978, as a response to this situation, the National Energy Act was established to promote the development of indigenous fuels including peat (U.S. Department of Energy, 1979). In 1979 the Department of Energy began a national peat inventory (U.S.D.O.E., 1980); the University of Rhode Island, Department of Geology began work on the project for Rhode Island in June, 1981, under the direction of the Rhode Island Energy Office.

Chapman Swamp was chosen as the first priority area for investigation because it represents the largest privately owned wetland area in Rhode Island. The swamp is located in southwestern Rhode Island in the town of Westerly; the Watch Hill and Ashaway, Connecticut-Rhode Island 7.5 minute quadrangles contain the study area (Fig. 1).

The purpose of this thesis is two-fold; 1) to explain the origin of the Chapman Swamp basin, and 2) to estimate the peat resources contained in the swamp. Secondary topics which will be addressed are; wetland classification, peat stratigraphy, and physical properties of the peat.

Heeley (1973), Hollands and Mullica, (1978) and Jordan (1978) related surficial geology to wetland occurrence in the northeastern U.S. Cameron (1981) related peat resource investigations to surficial geology in Maine. This thesis research is the first step in identifying similar

Fig. 1.--Location map of Chapman Swamp, Westerly Rhode Island.



MASS.
CONN.
R.I.
L.I.
43°
42°
41°
73°
72°
71°
70°
I-95
CONNECTICUT
RHODE ISLAND
N
CHAPMAN SWAMP
PAWCATUCK RIVER
AMTRAK-CONRAIL
CONN. RTE. 2
R.I. RTE. 3
CHAPMAN POND
R.I. RTE. 91
PAWCATUCK
WESTERLY
R.I. RTE. 78
R.I.
CONN.
U.S. RTE. 1
WESTERLY AIRPORT
U.S. RTE. 1-A
0
0.5
1.0 KM

relationships for southern New England peat deposits.

Previous investigations of the peat resource in the swamp are limited to locating the peat deposit on a map of agricultural resources (Jackson, 1840) and a cursory analysis of two peat samples by the U.S. Geological Survey during a national peat resource investigation (Soper and Osbon, 1922).

The town of Westerly contains 6600 households and 18,580 residents (U.S. Census Bureau, 1980). Electricity generated in Providence and southern Massachusetts at coal- and oil-fueled power plants is distributed to the town through a regional power grid. Peat can be used as a fuel in electrical power plants (Ekono, 1977) and is now being used in Finland and the U.S.S.R. (Technical Research Centre of Finland, 1981; Moore and Bellamy, 1974). If a peat-fueled power plant were built in Westerly, the town would become more energy self-sufficient and possibly benefit from lower electricity costs.

GEOLOGIC SETTING

The bedrock geology of the region surrounding the study area is complex. The Permian Narragansett Pier Granite underlies the area immediately to the east and under the swamp (Moore, 1967; Hermes et al., 1981). Metavolcanic rock dominates the area west of the swamp, and the area north of the swamp is underlain by the Potter Hill Granite Gneiss, Plainfield Formation (Blackstone Series, Quartzite and Gneiss) and Hope Valley Alaskite Gneiss (Feininger,

Table 1. -- Explanation of Surficial Geology map (Fig. 2, in pocket. Modified from Schafer (1965,1968).

HOLOCENE

Hwl	Fresh or brackish wetland
Hb	Beach face, berm top, dune
Hbwf	Overwash platforms and barrier flats
Hfl	Fluvial
Hflt	Fluvial terraces
Hac	Alluvium and colluvium
af	Artificial fill

WISCONSINAN

FLUVIAL/LACUSTRINE MORPHOSEQUENCES (kame, kame delta, kame terrace, kame plain, outwash plain)

4	Wkp, Wkt
3	Wkt
2b	Wkt, Wkd
2a	Wkt, Wkd, Wk
1	Wk, Wkt, Wop
Wkt	Uncorrelated kame terrace

MORAINE SYSTEMS

Wgm	Ground moraine
Wem	End moraine segment
Wam	Ablation moraine
Wem	Charlestown end moraine complex

PERIGLACIAL FEATURES

 Glacial spillway

 Ice fracture fillings

 Colluvial rampart

 Former position of stream tunnel

OTHER

 Bedrock outcrop

1965; Hermes et al., 1981).

By early Tertiary time several deep river valleys had been eroded into the bedrock (Schafer and Hartshorn, 1965), which are now filled by glacial sediments (Johnson, 1961a, b). Two of these valleys underlie the study area. The deepest valley extends to 33 m below sea level under the eastern half of the wetland, and the other extends to 20 m below sea level under the western half of the basin, while the surface of the wetland is 9.5 m above sea level. No data are available from which to determine the exact location of the valleys under the moraine but seismic surveys in Block Island Sound identified channels which are probably their continuation (McMaster and Ashraf, 1973a,b,c). The divides between these valleys are expressed by bedrock outcrops in the study area.

Wisconsinan glacial and Recent fluvial and swamp sediments dominate the surficial geology of the area (Schafer, 1965, 1968) (Fig. 2). Pre-Wisconsinan glacial ice covered the area (Schafer and Hartshorn, 1965) but no evidence of these glaciations is seen. The swamp is flanked on the west and east by till-mantled bedrock uplands and adjacent glacial fluvial and lacustrine deposits, to the south by the Charlestown Moraine complex, and to the north by the Pawcatuck River. Although no previous studies have specifically addressed the problem of paleogeography, the morpho-sequence units as mapped by Schafer (1965,1968) (Fig. 2, in pocket, Table 1) indicate that an ice-margin lake occupied the Chapman Swamp basin during late Woodfordian deglaciation.

Groundwater investigations in the area (Johnson, 1961a, b) indicate the surface of the wetland is below the average level of the regional water table and the surrounding sediment is very permeable suggesting the potential for a hydrologic connection between the wetland basin and the regional water table.

METHODS

Recently exposed excavations in the Crandall sand and gravel pit and vibracores in the pit and in Chapman Pond were used along with surficial geology maps (Schafer, 1965,1968) (Fig. 2, in pocket, Table 1) to interpret the paleogeography of the peat basin during deglaciation.

Panchromatic vertical aerial photographs at a 1:9600 scale, taken in March, 1980 were used to construct a 1:10,000-scale base map and to classify the wetland based on the U.S. Fish and Wildlife Service classification system (Cowardin et al., 1979). Modifications and verification of photo interpretations were made in the field. Preliminary maps prepared for the U.S. Fish and Wildlife Service National Wetland Inventory (1981) were used as a guide; however, these maps were not prepared to the desired detail and in some cases scrub-shrub wetland was mis-identified as emergent wetland. Mapped units were limited to those covering an area of more than 0.5 hectares.

Peat thickness was determined at 50 to 100 m intervals along 21 traverse lines across the axes of the wetland by use of steel probe rods. The rods consist of 3/8" steel in 2 m segments; the segments can be connected to reach depths limited only by the ability to extract the probe.

Peat stratigraphy was determined at 200 m intervals along the traverse lines with Eijkelkamp and MacCauley peat corers (Fig. 3). The configuration of the margin of the peat basin was defined away from the traverse lines by establishing short edge lines around the wetland margin, along which peat thickness and stratigraphy information was collected. The Eijkelkamp sampler returned a 1 m long, 5 cm diameter, cylindrical sample. Seventy-one of the 92 cores taken during the study were taken with the Eijkelkamp corer. In areas where the surface peat was saturated and fibrous, the top meter of peat was not recoverable with the Eijkelkamp sampler. In such a situation the stratigraphy was extrapolated from adjacent cores and the surface meter was sampled by hand. The MacCauley sampler returned a 1 m long, 5.8 cm diameter, half-cylinder sample; twenty-one of the 92 cores were taken with the MacCauley. The main advantages of the MacCauley sampler are the elimination of sample contamination and more reliable sample recovery.

As cores were taken, the 1 m segments were placed in half-round, 10 cm diameter, core trays and sealed in tubular plastic bags for transport out of the field for further analysis.

Preliminary descriptions of the peat cores were made as

Fig. 3.--Coring with the MacCauley peat corer. When the desired sampling depth is reached the corer is twisted, confining a sample behind the fin (arrow).

the cores were extracted. Initial classification was based on an estimate of degree of decomposition and, when possible, identification of dominant plant remains. Samples were assigned to the fibric, hemic or sapric category (Soil Survey Staff, 1975) based on a simple field test: When squeezed with moderate pressure in the hand, if clear or nearly clear water was expelled, the sample was classified as fibric; if the water was sediment-rich but some sample remained in hand, it was classified as hemic; and if the entire sample was forced between the fingers it was classified as sapric.

In samples where plant fibers were identifiable, moss and reed-sedge peat was delineated based on the U.S. Bureau of Mines peat classification used in other peat investigations (Cameron, 1970,a,b,1975; Boothroyd, et al., 1979; Davis, et al., 1980; Peters, 1981). Wood peat was identified based on descriptions by Dachnowski (1924) and Heinselman (1963, 1970). Detailed logging was carried out at the laboratory to check the field identification of the plant remains.

Twenty-seven 450 g (1 pound) samples (approximately 1/2 of a 50 cm segment of an Eijkelkamp sample) were chosen from cores in all areas of the wetland representing all of the peat types. The samples were sent to the U.S. Department of Energy, Grand Forks Energy Technology Center for proximate, ultimate and calorific analyses. Other samples were chosen from each stratigraphic unit of each core, to be analyzed for moisture, fiber and ash content. Twenty segments of peat core, from 10 to 50 cm long representing all of the peat types in the wetland were used to determine bulk density.

Total and fuel-grade peat isopach maps were constructed from the peat thickness data. Peat volume was determined by measuring the area covered by each contour interval with a rolling disk digital planimeter and multiplying by the isopach interval. Fuel-grade peat tonnage was calculated using an estimate of the average bulk density.

Laboratory Methods

Appendix 1 is a step-by-step description of the laboratory procedures used in this study; a summary follows.

Moisture content, fiber content and bulk density were determined following the methods of Boelter (1969), and the American Society of Testing and Materials (1978). Moisture and fiber were determined for 299, 100 g samples. One half of each sample was weighed to establish bulk weight, and then reweighed after drying in a mechanical convection oven for 16-24 hours, and a percent moisture determined. This sample was saved for use in the ash analysis.

The second half of each sample was weighed and soaked in a 5.0% calgon solution for 16 to 24 hours to aid dispersion. After soaking, the sample was passed through a 0.25 mm sieve. Caution was exercised to prevent the further breakdown of the fibers during this process. The sieved sample was then dried at 105°C for a minimum 16 hours. Wood fragments with largest dimension greater than 2 cm were separated from the fiber. Each fraction was weighed and a wood and fiber content was calculated.

Bulk density was determined by drying a known volume of peat and weighing the dry sample; the resulting value of dry weight divided by volume was the bulk density.

Ash content was determined following ASTM (1978) guidelines. Two grams of the dry moisture determination sample was incinerated at 550°C in a muffle furnace for one to two hours. The ash was weighed after cooling and a moisture-free ash content determined.

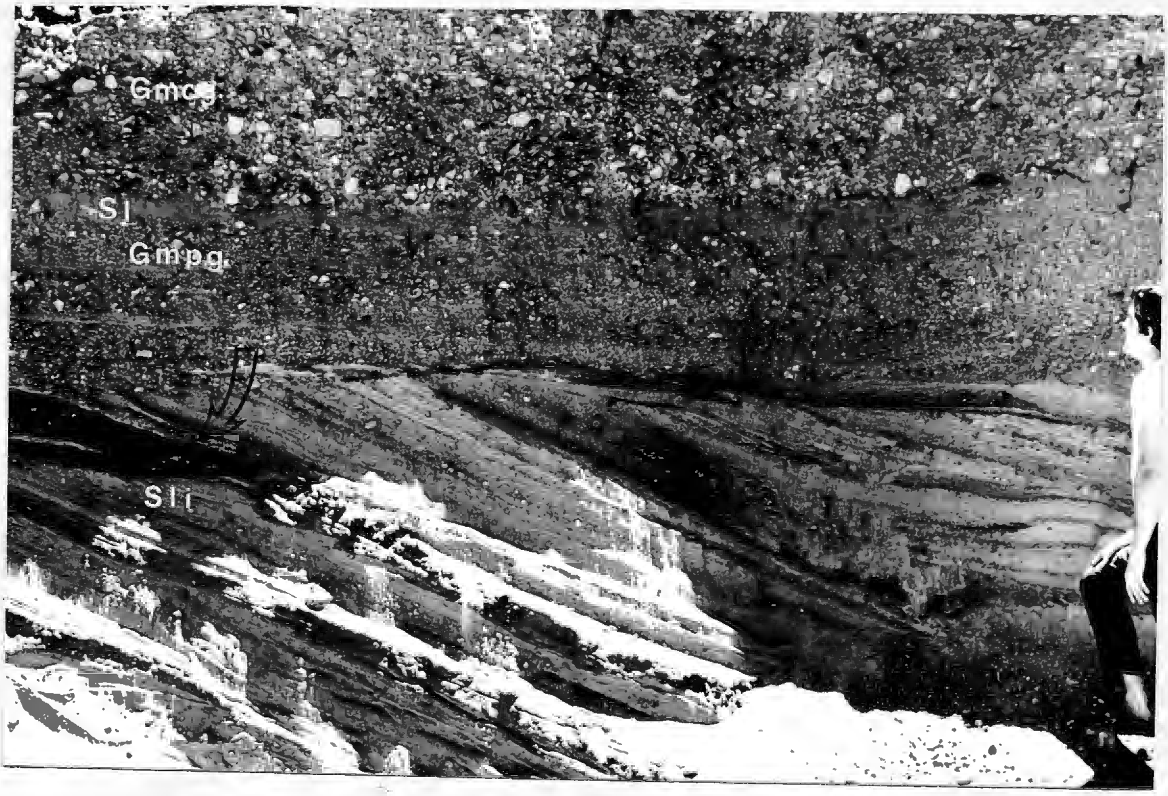
RESULTS

Glacial Stratigraphy

The surficial geology as mapped by Schafer (1965, 1968) was modified by assigning morphological classifications (kame, kame plain, etc.) to the landforms (Fig. 2, in pocket, Table 1). While examining recent excavations on the east margin of the wetland in the Crandall sand and gravel pit and two vibracores from the pit and Chapman Pond (Fig. 2) nine facies, representing four facies groups were identified (Fig. 4, in pocket).

<u>Clast-supported gravel (Gm)</u>.--Three varieties of this facies group were observed. The coarse cobble variety is composed of 13 cm cobbles (avg. largest clast size) with a coarse sand and granule matrix (Gmcg, Fig. 5). A finer cobble variety (Gmc) contains 6 cm cobbles within a coarse sand

Fig. 5.--Facies Gmcg, Gmpg, Sl and Sli (Fig. 4, in pocket, stratigraphic section 1) deposited in delta plain and delta-front depositional environments. Arrow points to conformable contact.



Gmcg.
Sl
Gmpg.
Sli

matrix. The third variety is a plane-laminated pebble gravel (3-4 cm) (Gmpg) with a granule and coarse sand matrix interlaminated with coarse sand.

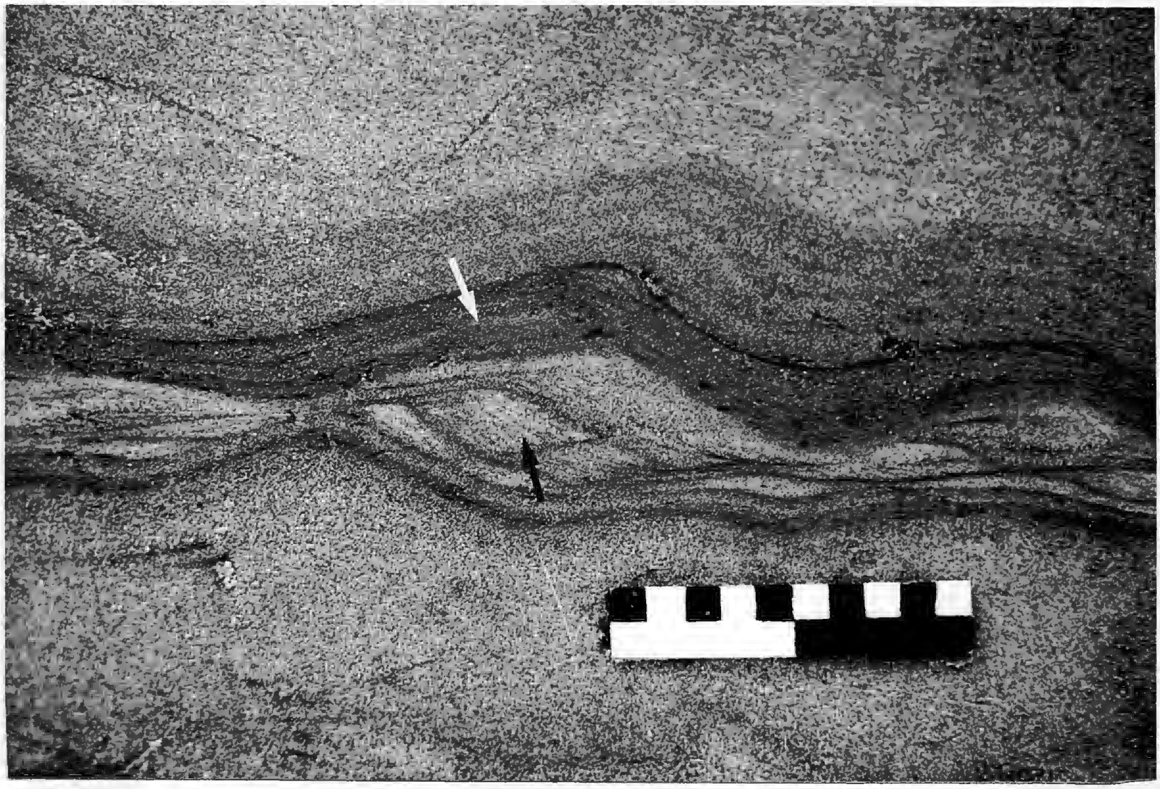
These facies represent deposition in longitudinal bars on braided glacial outwash streams. This interpretation is based on simlarities between these facies and bars on modern alluvial fans in Alaska, Canada and Iceland (Gustavson, 1974; Boothroyd and Ashley, 1975; Rust, 1975). Gmcg represents deposition in an upper alluvial fan environment, Gmc in a middle fan and Gmpg a distal fan environment.

Plane-laminated sand (Sl).-- This group contains two facies: a horizontally laminated medium and coarse sand (Sl) and a medium and coarse sand with granules inclined at 14 to 30 degrees (Sli) (Fig. 5). The horizontal facies occurs in discontinuous lenses associated with facies Gm. This facies represents deposition on the flanks of gravel bars during low flow conditions. The inclined facies (Sli) was deposited in a delta-front environment. This interpretation is based on the similarity of this facies and delta-front facies of the Glacial Lake Hitchcock deltas in Massachusetts (Gustavson, Ashley and Boothroyd, 1975).

Fine sand and silt (F).--Three facies of this group were observed. Facies Fr is characterized by small scale trough and climbing ripple-drift cross-stratification (Fig. 4, in pocket, 6) Fl is plane laminated fine sand and silt with occasional medium sand lenses and Fd is deformed fine sand and silt (Fig. 7). These facies were deposited in a

Fig. 6.--Type A (black arrow) and B (white arrow) ripple drift cross-stratified sand and silt (Fr) at station 3 (Fig. 4, in pocket). Flow direction is left to right. Scale is 10 cm. This facies represents deposition on the pro-delta slope.

Fig. 7.--Deformed sand and silt deposited in a pro-delta slope environment (Fd), scale is 1 m. Deformation was caused by dewatering of the sediment associated with ice block collapse and loading.



pro-delta slope environment. This interpretation is based on their similarity with sediments found in modern glacial lakes in Alaska (Gustavson, 1975) and Wisconsinan glacial lakes in Massachusetts (Ashley, 1975; Gustavson, Ashley and Boothroyd, 1975) and Canada (Shaw, 1975).

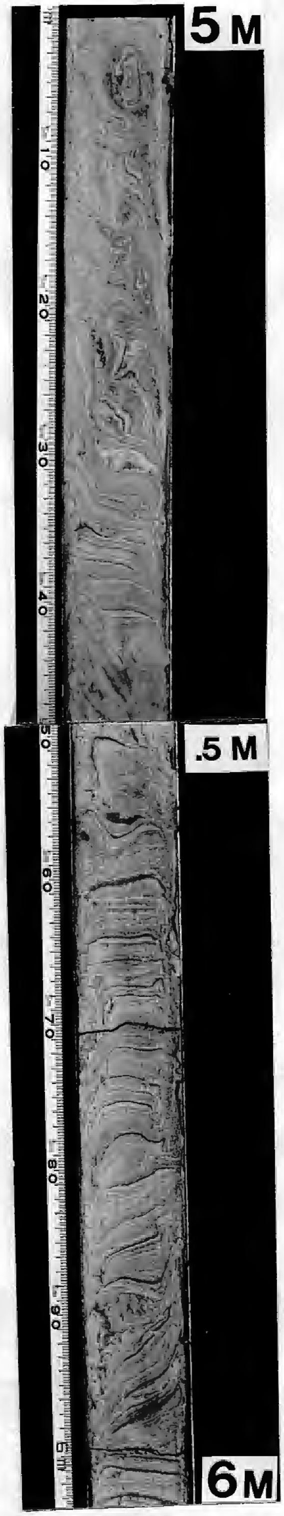
Laminated clay-rich silt (Flc).-- This facies consits of 0.1 to 8.0 cm thick clay-rich laminae which forms a drape over facies Fr, Fl and Fd (Fig. 4 (in pocket), 8). This facies represents deposition from a still water column in a frozen lake. Similar facies are found in Wisconsinan lake deposits of Massachusetts (Ashley, 1975), and in modern glacial lakes in Alaska (Gustavson, 1975).

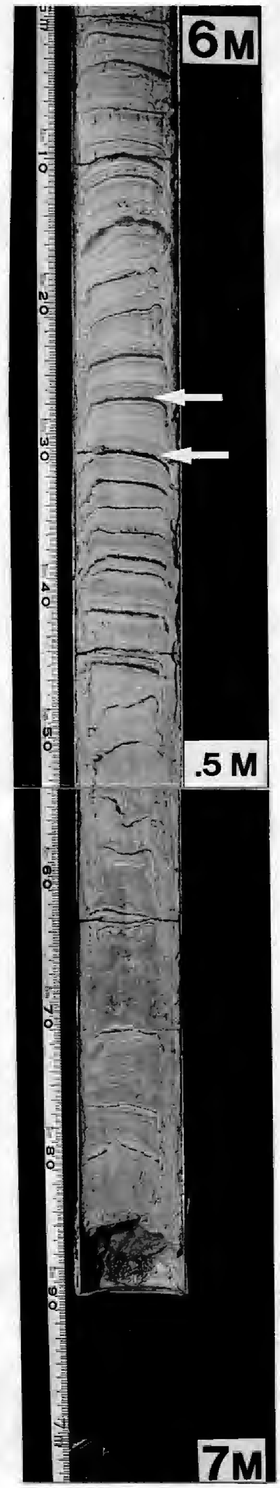
Wetland Classification

The U.S. Fish and Wildlife Service defines wetlands as areas of transition between terrestrial and aquatic systems where the land is covered by shallow water or the water table is at or near the surface (Cowardin et al., 1979). This environment is conducive to the preservation of plant material in the form of peat (Moore and Bellamy, 1974; Soper and Osbon, 1922). Plant communities on the wetland surface are indicative of the peat types near the surface (Abromova, 1965; Boch, 1965; Ysnopol'skaya, 1965). Consequently, knowledge of the present conditions in the wetland environment is necessary to understand the depositional environments of peat.

The U.S. Fish and Wildlife Service classification System for wetland and deepwater habitats has a hierarchical

Fig. 8.--Laminated silt (Fl) (light color) and clay-rich silt (Flc) (dark color) from vibracore 2 (Fig. 4, in pocket). These facies represent deposition in a distal lake bottom environment. The sequence between the arrows represents one year of deposition (distal varve).


5 M
.5 M
6 M


6M
.5 M
7M

structure as shown below (Cowardin, et al., 1979).

System (broadest classification)

Subsystem

Class

Subclass

This classification is based on hydrologic, geomorphic, chemical and biological factors, with modifiers for water regime, water chemistry and soils applied to Classes and Subclasses. Water chemistry information was not collected during this study so the modifier is not used. Addition of a life form modifier is helpful in using the classification with existing wildlife habitat evaluation systems (F. Golet, pers. comm.).

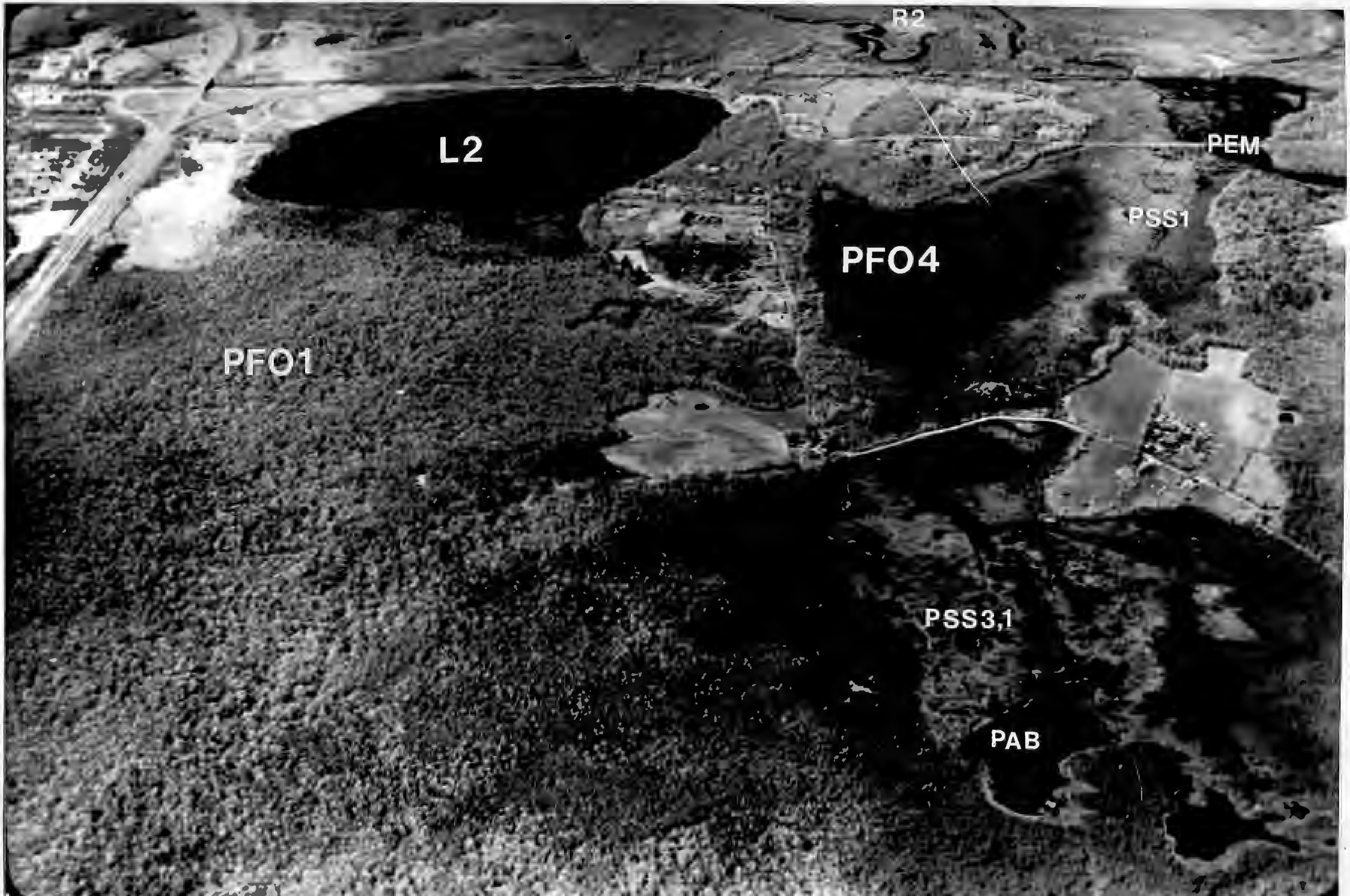
There are three Systems represented in the study area (Fig. 9, in pocket, Table 2): Riverine, Lacustrine and Palustrine. The Pawcatuck River in the northern part of the study area (Fig. 10) is classified as Riverine System, Lower Perennial Subsystem (Cowardin, et al., 1979), (R2UB2, Fig. 9). The river consists of a meandering channel, with depth along the thalweg of 2 to 3 m. The river is flanked by Palustrine wetland and natural levee uplands; water level is controlled by several small dams which were constructed in the nineteenth century to supply water power to mills (Guthrie, et al., 1973).

Chapman Pond is a shallow, peat-bottomed pond in the northwest corner of the study area. Old maps of Westerly indicate the pond has expanded in size since damming of the

Table 2. -- Explanation of Wetland Classification map (Fig. 9, in pocket). Based on U.S. Fish and Wildlife Service System (Cowardin, et, al., 1979).

RIVERINE SYSTEM - LOWER PERENNIAL SUBSYSTEM	
STREAMBED	
R2UB2	Sand bottom
LACUSTRINE SYSTEM - LITTORAL SUBSYSTEM	
UNCONSOLIDATED BOTTOM	
L2UB4	Organic bottom
AQUATIC BED	
L2AB3	Rooted vascular plants
EMERGENT	
L2EM2n,b	Nonpersistent, broad-and narrow-leaved
PALUSTRINE SYSTEM	
AQUATIC BED	
PAB3	Rooted vascular plants
PAB3f	Rooted vascular plants (floating leaved)
EMERGENT	
PEM1n	Persistent, narrow leaved
PEM2b	Nonpersistent, broad leaved
SCRUB-SHRUB	
PSS1c	Compact shrub (broad-leaved, deciduous)
PSS1t	Tall shrub (broad-leaved, deciduous)
PSS1s	Sapling (broad-leaved, deciduous)
PSS3c	Compact shrub (broad-leaved, evergreen and deciduous)
PSS4s	Sapling (needle leaved, evergreen)
FORESTED	
PFO1	Tree (broad leaved, deciduous)
PF04	Tree (needle leaved, evergreen)

Fig. 10.--Chapman Swamp, view is to north. Chapman Pond is in upper left corner, Westerly town landfill is at southwest corner of pond and Pawcatuck River is seen at top right. Wetland classification abbreviations are explained in Table 2. Photo taken May 8, 1981.


R2
L2
PEM
PSS1
PFO4
PFO1
PSS3,1
PAB

rivers (Jackson, 1840; U.S.G.S., 1891). Local residents speak of a former corn field that is now covered by water in the southeast corner of the pond. The pond is classified as Lacustrine System, Littoral Subsystem, with three classes accounting for 10% of the total wetland area (Table 3, Fig. 10). The center of the pond is characterized by a peat bottom with less than 30% coverage by aquatic plants (L2UB4, Fig. 9). Around this center area is a rooted vascular aquatic bed (L2AB3, Fig. 9) dominated by white water lily (Nymphaea odorata), spatterdock (Nuphar sp.) and bladderwort (Utricularia sp.). Around the margin of the pond, except the south shore, is narrow- and broad-leaved emergent wetland (L2EM2n,b), dominated by pickerelweed (Pontederia cordata), arrow arum (Peltandra virginica) and bayonet rush (Juncus militaris). The water regime in the pond is intermittently exposed around the edge to permanently flooded in the center.

The aquatic bed Class of the Lacustrine System is the depositional environment of aquatic peat (Heinselman, 1963, 1970; Dachnowski, 1924). The colloidal plant remains that make up the aquatic peat are a component of sedimentary peat (Cameron, 1970a,b, 1975; Peters, 1981). The occurrence of this peat type on the bottom of the pond is limited to 1 to 2 cm, too thin to be included in the peat core logs.

Ninety percent of the wetland area is in the Palustrine System (Table 3). No Subsystems are designated in this System and four Classes and twelve Subclasses are in the

Table 3. -- Areas of Wetland Classes and Subclasses.

SYSTEM	CLASS	SUBCLASS	LIFE-FORM	SYMBOL	AREA (ha)	AREA %
Lacustrine	Unconsolidated bottom	Organic	NA	L2UB4	24.7	3.6
	Aquatic bed	Rooted vascular	Undiff.	L2AB3	39.0	5.7
	Emergent	Nonpersistent	Undiff.	L2EM2n,b	5.5	0.8
Palustrine	Aquatic	Rooted vascular	Undiff.	PAB3	3.4	0.5
			Floating-leaved	PAB3f	5.5	0.8
	Emergent	Persistent	Narrow-leaved	PEM1n	1.7	0.2
		Nonpersistent	Broad-leaved	PEM2b	2.0	0.3
	Scrub-shrub	Broad-leaved, deciduous	low, compact	PSS1c	60.9	8.9
			Tall	PSS1t	23.3	3.4
			Sapling	PSS1s	8.9	1.3
		Broad-leaved, evergreen and deciduous	Low, compact	PSS3c,1c	28.8	4.2
		Narrow-leaved, evergreen	Sapling	PSS4s	0.7	0.1
	Forested	Broad-leaved, deciduous	Tree	PFO1	345.9	50.5
		Needle-leaved, evergreen	Tree	PFO4	134.7	19.7
				TOTAL	685.0	100.0

study area.

Aquatic Bed Class.-- The Aquatic Bed Class covers 1.3% of the wetland area (Table 3, Fig. 9, 11). Subclasses represented are: (1) rooted vascular plants with floating leaves (PAB3f) dominated by white water lily (*Nymphaea odorata*) and spatterdock (*Nuphar spp.*), and (2) rooted, submergent and floating leaved vascular plants characterized by the addition of bladderwort (*Utricularia spp.*) to the previously mentioned species. The water regime is intermittently exposed to permanently flooded and no soil modifier is applied. The Palustrine aquatic bed class is another depositional environment of aquatic peat.

Emergent Class.-- The Emergent Class covers 0.5% of the wetland area (Table 3, Fig. 9, 11). Two Subclasses are represented in the study area and both have a semi-permanently flooded water regime. The persistent subclass with a narrow-leaved life form (PEM1n) is dominated by tussock sedge (*Carex stricta*) (Fig. 12). The non-persistent Subclass, broad-leaved life form (PEM2b) is dominated by pickerelweed (*Pontederia cordata*) and arrow arum (*Peltandra virginica*). Water depth in these environments ranges from 0.5 to 1 m in the non-persistent subclass to 1 to 2 m in pools between the tussocks of sedge. These subclasses are the depositional environment of hemic and fibric reed-sedge peat (Dachnowski, 1924 (reed and sedge peats); Heinselman, 1963, 1970 (herbaceous peat); Peters, 1981) (cores V-A, V-C, App. 2).

Fig. 11.--View looking southeast of northeast corner of wetland. RI 91 crosses the wetland; the Crandall Sand and Gravel Pit is at the top of the photo. See Table 2 for wetland classification explanation. Photo taken May 8, 1981.

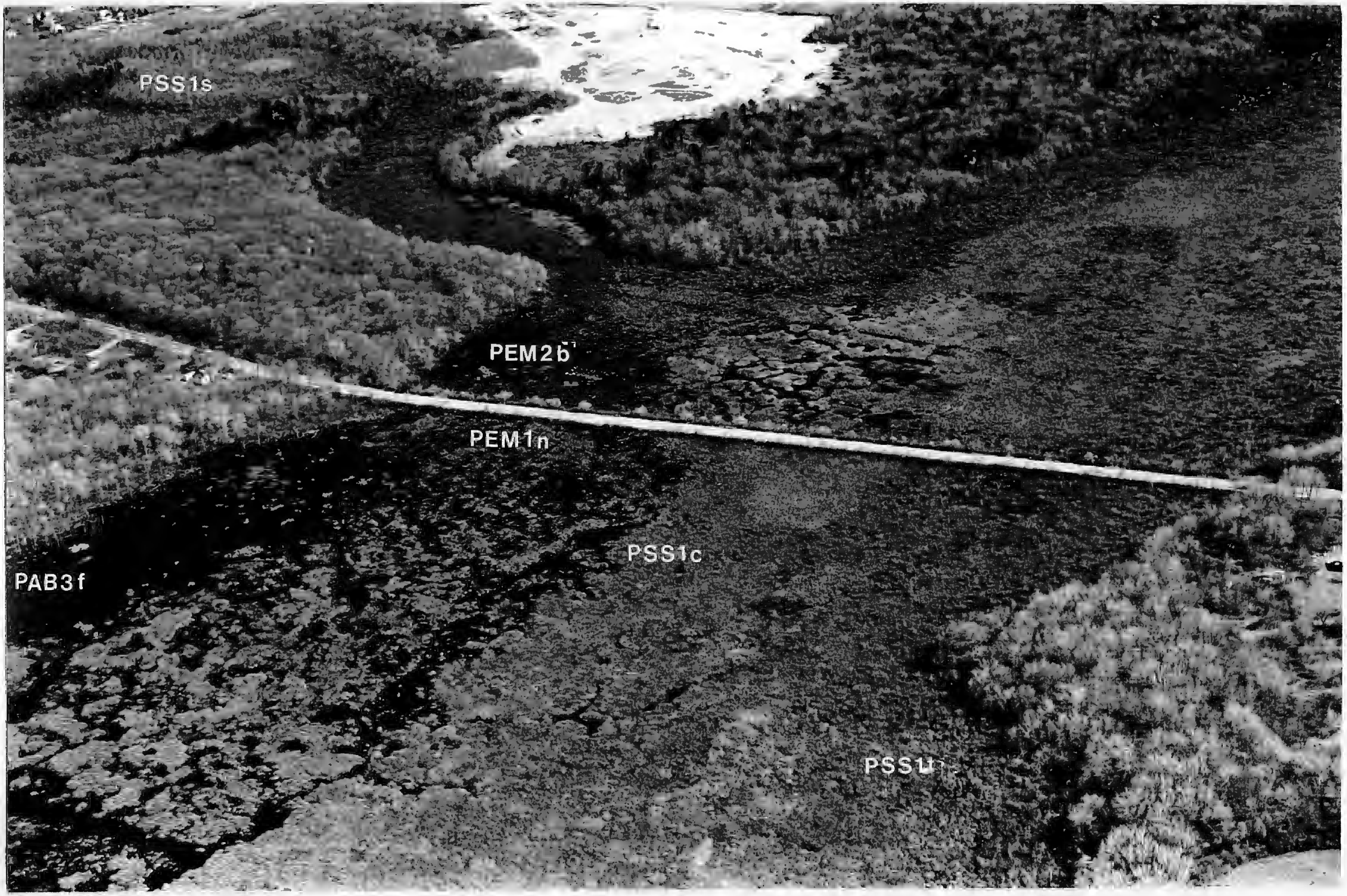

PSS1s
PEM2b
PEM1n
PSS1c
PAB3f

Fig. 12.--Narrow-leaved persistent emergent wetland (PEM1n), dominant plant is tussock sedge (_Carex stricta_). View is to north from RI 91. Photo taken in November 1981.

Fig. 13.--Tall, broad-leaved deciduous scrub-shrub wetland (PSS1t); dominant plants are sweet pepper-bush (_Clethra alnifolia_), highbush blueberry (_Vaccinium corymbosum_) and red maple (_Acer rubrum_). View is to the south from RI 91. Photo taken in July, 1981.

Scrub Shrub Class.-- The Scrub-Shrub Class covers 17.9% of the wetland area (Table 3, Fig. 9). Three Subclasses are represented in the study area. The deciduous broad-leaved Subclass (Fig. 11) contains three life-form units: (1) low, compact shrubs (PSS1c) dominated by sweet gale (Myrica gale), highbush blueberry (Vaccinium corymbosum) and poison ivy (Toxicodendron radicans); (2) tall shrubs (PSS1t) dominated by sweet pepper-bush (Clethra alnifolia), and highbush blueberry (Vaccinium corymbosum) (Fig. 13); and (3) saplings dominated by red maple (Acer rubrum). The water regime associated with the shrub life-forms is seasonally to semi-permanently flooded, and the sapling life-forms are seasonally flooded.

The compact scrub-shrub wetland occurs in areas where shrubs have become dominant on the sedge tussocks. Distinct mounds and pools with total relief of 0.5 to 1.5 m are common with small areas (20 m across) of floating mat. The contact between the tall and the compact shrubs is a gradational one, with the same species occurring in both environments. The changes encountered when crossing from compact to tall shrubs are: increase in shrub height to 2 to 3 m, decrease in the abundance of emergent plants, and decrease in mound and pool relief. In terms of peat type being deposited, the change is from hemic woody reed-sedge to hemic and sapric wood peat. Understory species associated with the sapling life form are commonly low shrubs with some emergents in small open areas. Sapric wood

Fig. 14.--View looking north of southeast part of wetland. Pound Road crosses top of photo. See Table 2 for wetland classification explanation. Photo taken May 6, 1982.


PSS4s
PSS3c/1c
PAB3
PFO4

Fig. 15.--Compact broad-leaved evergreen and deciduous scrub-shrub wetland (PSS3c,1c) and Needle-leaved evergreen forested wetland (PFO4). Dominant plants are leather leaf (Chamaedaphne calyculata), black huckleberry (Gaylussacia baccata), Atlantic white cedar (Chamaecyparis thyoides) and sphagnum moss (Sphagnum spp.). Photo taken November, 1981.


PFO4
PSS3c
PSS1c

peat is at the surface in this environment.

The broad-leaved evergreen Subclass (Fig. 14, 15) contains the low compact life form (PSS3c) dominated by leatherleaf (Chamaedaphne calyculatta) and occurs interspersed with compact broad-leaved deciduous shrubs (PSS1c) dominated by black huckleberry (Gaylussacia baccata). Due to the interspersed nature of these subclasses they were mapped as one unit (PSS3c,1c, Fig. 9, in pocket, Table 2). Some significant subordinate plants in this area are sphagnum moss (Sphagnum sp.) which completely covers the wetland surface, sundew (Drosera sp.) and pitcher plant (Sarracenia purpurea). This class is characterized by a saturated, floating mat with scattered open water areas supporting aquatic plants. In areas between dense shrubs, where the moss is exposed, the surface peat is fibric moss with very little wood (core VII-E; App. 2). The surface peat beneath the shrubs is fibric woody moss peat.

The needle-leaved evergreen Subclass, with a sapling life-form unit (PSS4s), is found in small clumps within the broad-leaved evergreen Subclass (Fig. 14). The dominant species is Atlantic white cedar (Chamaecyparis thyoides), with ground cover of sphagnum moss, a saturated water regime, and fibric mossy wood peat at the surface.

Forested Class.-- The Forested Class covers 69.9% of the wetland area (Table 3, Fig. 9). The broad-leaved deciduous Subclass (Fig. 10, 16) is dominated by red maple (Acer

Fig. 16.--Broad-leaved deciduous forested wetland (PFO1). Dominant plants are red maple (*Acer rubrum*), swamp azalea (*Rhododendron viscosum*) and sweet pepper-bush (*Clethra alnifolia*). Photo taken July, 1981.

rubrum), with understory most commonly of sweet pepper-bush (Clethra alnifolia), highbush blueberry (Vaccinium corymbosum), rhododendron (Rhododendron maximum) and greenbriar (Smilax spp.). The needle-leaved evergreen Subclass (PF04) (Fig. 14, 15) is dominated by Atlantic white cedar (Chamaecyparis thyoides) with rhododendron (Rhododendron maximum), and highbush blueberry (Vaccinium corymbosum) the most common understory species.

Well developed mounds and pools, with total relief of 20 to 40 cm are found throughout both forested subclasses. Water levels in the forested wetlands during the field study (June and July, 1981) were at, or less than, 10 cm below the peat surface. Sapric wood peat is at the surface in this environment (core VI-H, App. 2), and the lack of surface water streams results in very little terrigenous sediment being deposited along with the peat.

Peat Classification

The peat samples were classified based on the macroscopic plant fragments they contained. The three general peat types identified are moss, reed-sedge and wood. Moss and reed-sedge are designations recognized by the U.S. Bureau of Mines and are commonly used in peat resource investigations (Cameron, 1970a, b, 1975; Boothroyd, et al., 1979; Davis, et al., 1980; Peters, 1981). These peat types are also similar to types described by Dachnowski (1924), and Heinselman (1963, 1970), who subdivided the reed-sedge type. The wood peat type was described by

Dachnowski (1924) and Heinselman (1963,1970), but is not included in the U.S. Bureau of Mines classification.

Moss peat (Fig. 17) is composed of coarse to fine fibrous moss fragments usually yellow brown to brown in color when fresh, with a felt-like, porous or spongy texture.

Reed-sedge peat (Fig. 18) is composed of the remains of narrow-leaved emergent and associated herbaceous plants. It ranges from brown to black in color and is fibrous but does not exhibit the felty texture of a moss peat.

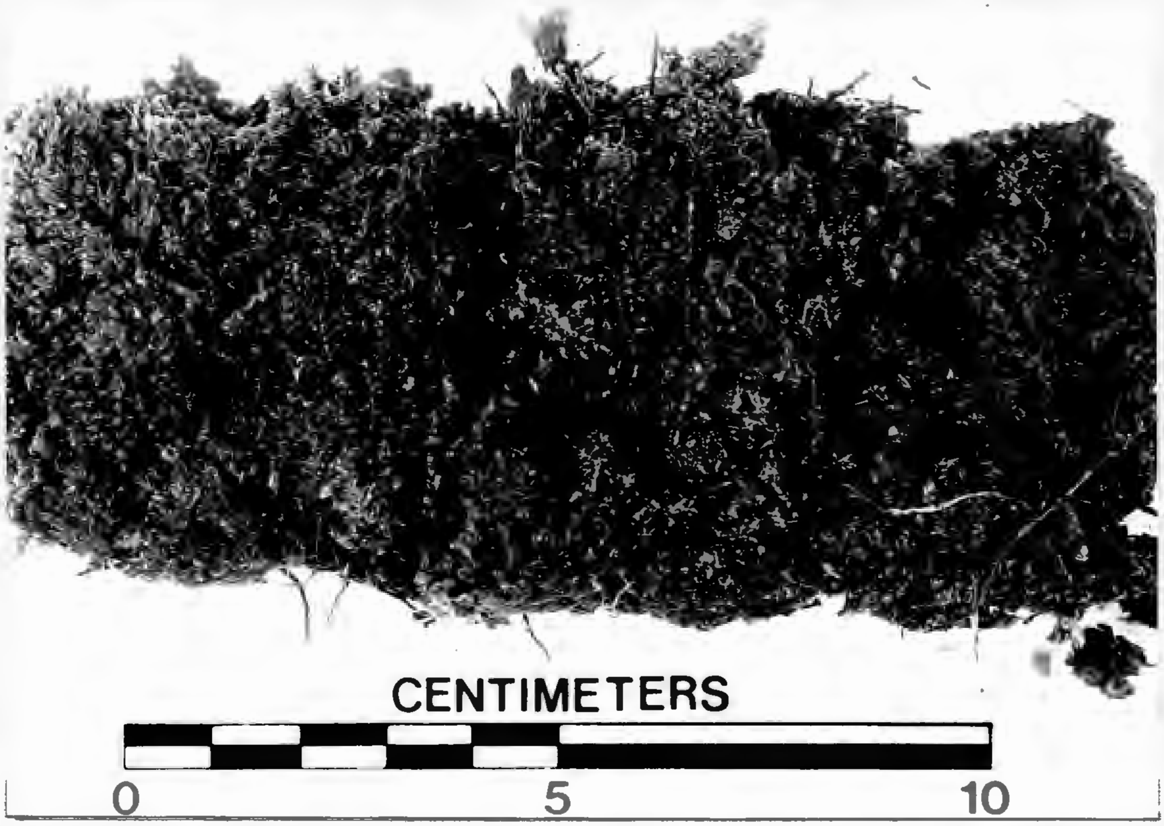
Wood peat (Fig. 19) is composed of woody plant fragments in a ground mass of sapric material. Colors range from red-brown to black.

Although stratigraphic units of pure peat types do occur in the study area much of the stratigraphy consists of gradations between the three peat type end-members (App. 2).

The secondary classification by degree of decomposition was based on the fiber content of the peat. This classification normally uses the >0.15mm or >0.10mm fiber fraction (Soil Survey Staff, 1975; Boelter, 1969). The >0.25 mm fiber size fraction was chosen for this study to be used as a predictor of bulk density. Determination of the decomposition class boundaries for >0.25 mm was done using the bulk density limits of the decomposition classes (Table 4) and the curve developed by Boelter (1969), relating fiber content and bulk density. The bulk density limits of hemic

Fig. 17A.--Fibric moss peat, 45-55 cm segment of core XXI-E (App. 2).

Fig. 17B.--Hemic moss peat, 100-110 cm segment of core XXI-E (App. 2).


CENTIMETERS
0
5
10

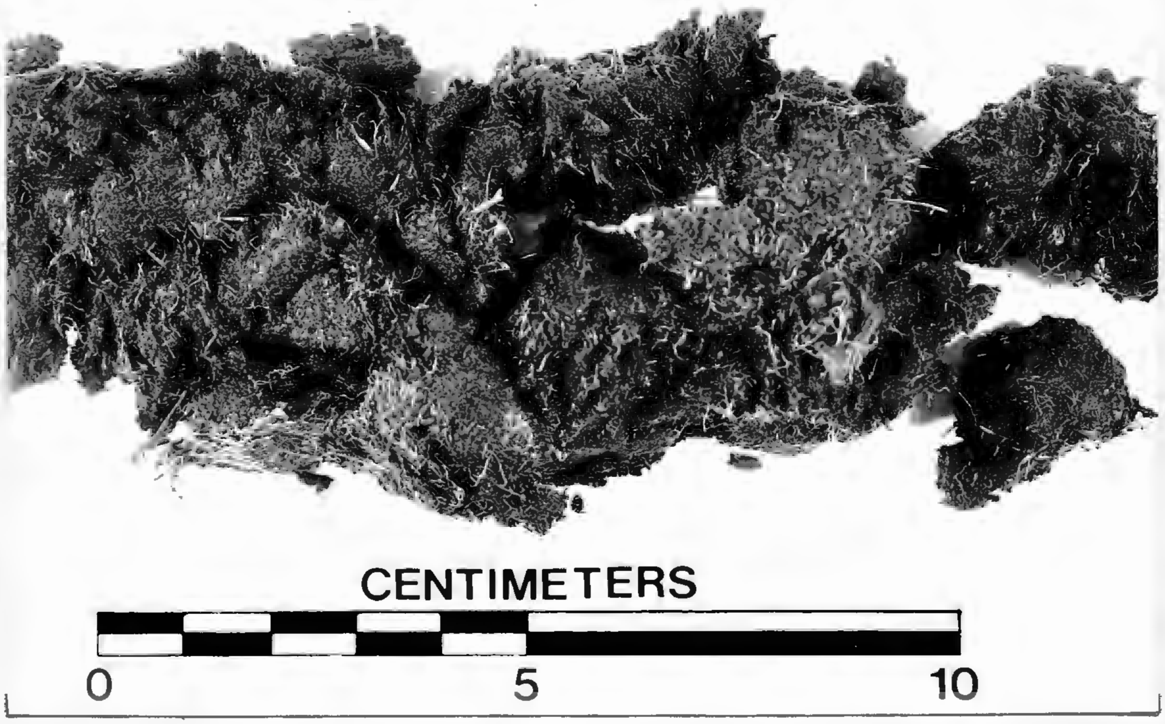
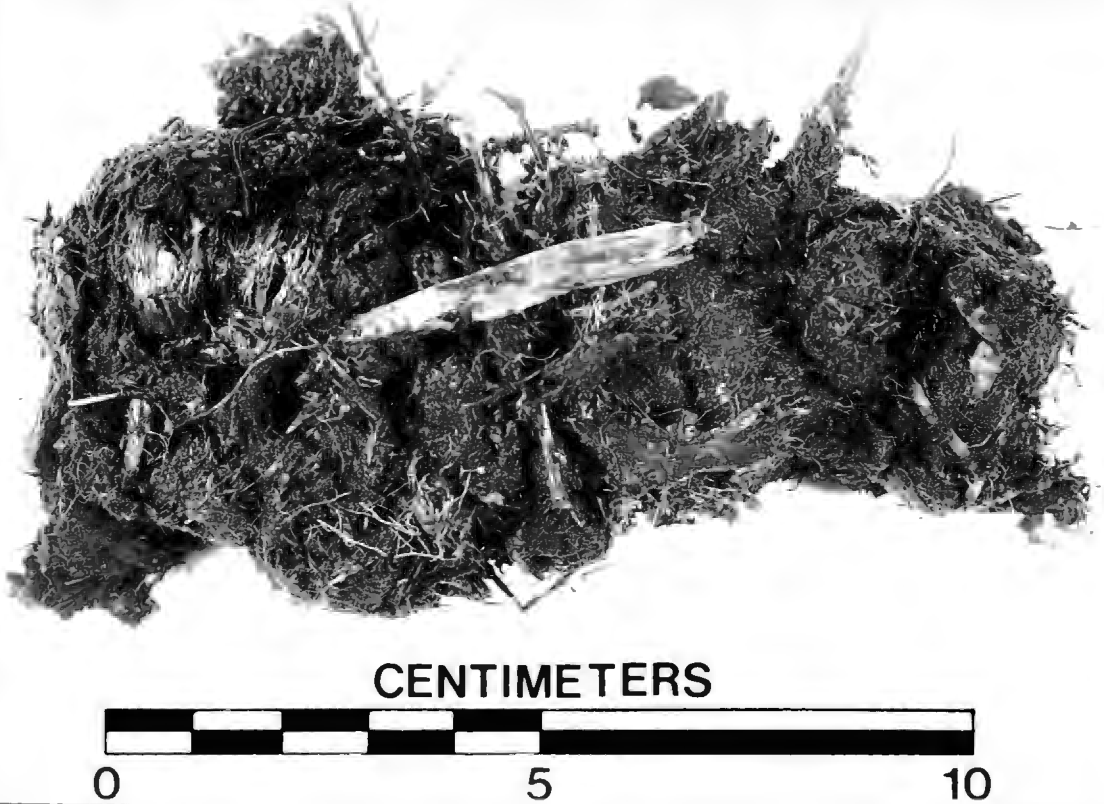

CENTIMETERS
0
5
10

Fig. 18.--Fibric reed-sedge peat, 70-80 cm segment of core XXI-E (App. 2).

Fig. 19.--Fibric wood peat with moss peat matrix, 10-20 cm segment of core XXI-E (App. 2).


CENTIMETERS
0
5
10


CENTIMETERS
0
5
10

Table 4.--Decomposition classification boundaries.

FIBER SIZE	PROPERTY	DECOMPOSITION CLASS FIBRIC	HEMIC	SAPRIC
>0.10mm	Fiber	>67%	33-67%	<33%
	Bulk Density	<0.075	0.075-0.2	>0.20
>0.25mm	Fiber	>55%	20-55%	<20%
	Bulk Density	<0.075	0.075-0.20	>0.20

peat are 0.075 g/cc to 0.200 g/cc. The equivelant fiber contents as determined from the curve of Boelter are 20% to 55%. The resulting class limits are: sapric, <20% fiber; hemic, 20 to 55% fiber; and fibric, >55% fiber.

Fuel Analysis

Appendix 3 contains the results of the proximate, ultimate and calorific analyses done by the U.S. Department of Energy Fuel Technology Center. Table 5 is a summary of the data classified by peat type. The overall result of the analyses is that wood peat is of the highest fuel value (average calorific value of 9940 BTU/lb, moisture free), reed-sedge peat is intermediate (8355 BTU/lb, MF) and moss peat is of the lowest quality (5979 BTU/lb, MF).

Fuel-grade peat as defined by the Department of Energy must: (1) have a minimum, moisture free calorific value of 8000 BTU/lb; (2) contain less than 25% ash; (3) be at least 1.5 m (5 feet) thick; and (4) cover at least 12.5 ha/sq km (80 acres/sq mi) (Davis, et al., 1980). All of the wood peat samples analyzed are fuel-grade, but peat quality varies in moss and reed-sedge samples.

Proximate analysis is done to determine the ash content, volatile matter and fixed carbon of peat samples (Ergun, 1979). The direct relationships of volatile matter and fixed carbon with fuel value, and the inverse relationship of ash content with fuel value in peat is well documented (Otte and Ingram, 1980; Severson, et al., 1980; Ingram and Otte, 1981,a ,b; Peters, 1981). Similar

Table 5. -- Summary of proximate analyses performed by the Department of Energy. See Appendix 3 for complete results.

PEAT TYPE		% MOISTURE	% VOLATILE MATTER (MF)	% FIXED CARBON (MF)	% ASH (MF)	CALORIFIC VALUE BTU/lb
Wood n= 5	Mean	85.8	63.0	30.8	6.2	9940
	Max.	88.6	64.3	32.8	11.4	10803
	Min.	83.9	61.3	27.3	3.2	9535
Reed-sedge n= 8	Mean	88.5	51.9	26.7	21.4	8355
	Max.	99.6	61.9	33.1	50.2	10520
	Min.	84.9	35.9	13.9	5.2	5443
Moss n=11	Mean	86.5	40.8	17.9	41.3	5979
	Max.	92.0	56.7	28.5	80.4	8852
	Min.	71.6	14.2	5.4	15.4	1823

relationships are seen in Chapman Swamp peat samples (Fig. 20, 21). These relationships are examples of the use of proximate analysis to determine the calorific value of peat (Ergun, 1979). The low cost and limited equipment required to determine ash content allows easy and inexpensive estimation of calorific value.

Ultimate analysis is done to determine the elemental composition of the peat (Ergun, 1979). Carbon, hydrogen and oxygen content affect the calorific value, and nitrogen and sulfur are potential pollutants during combustion (Ergun, 1979; Essenhigh, 1979). The levels of sulfur in peat from Chapman Swamp are below levels established for low sulfur coals (<1.0%)(Eliot, 1978).

Ash, Moisture and Fiber Content

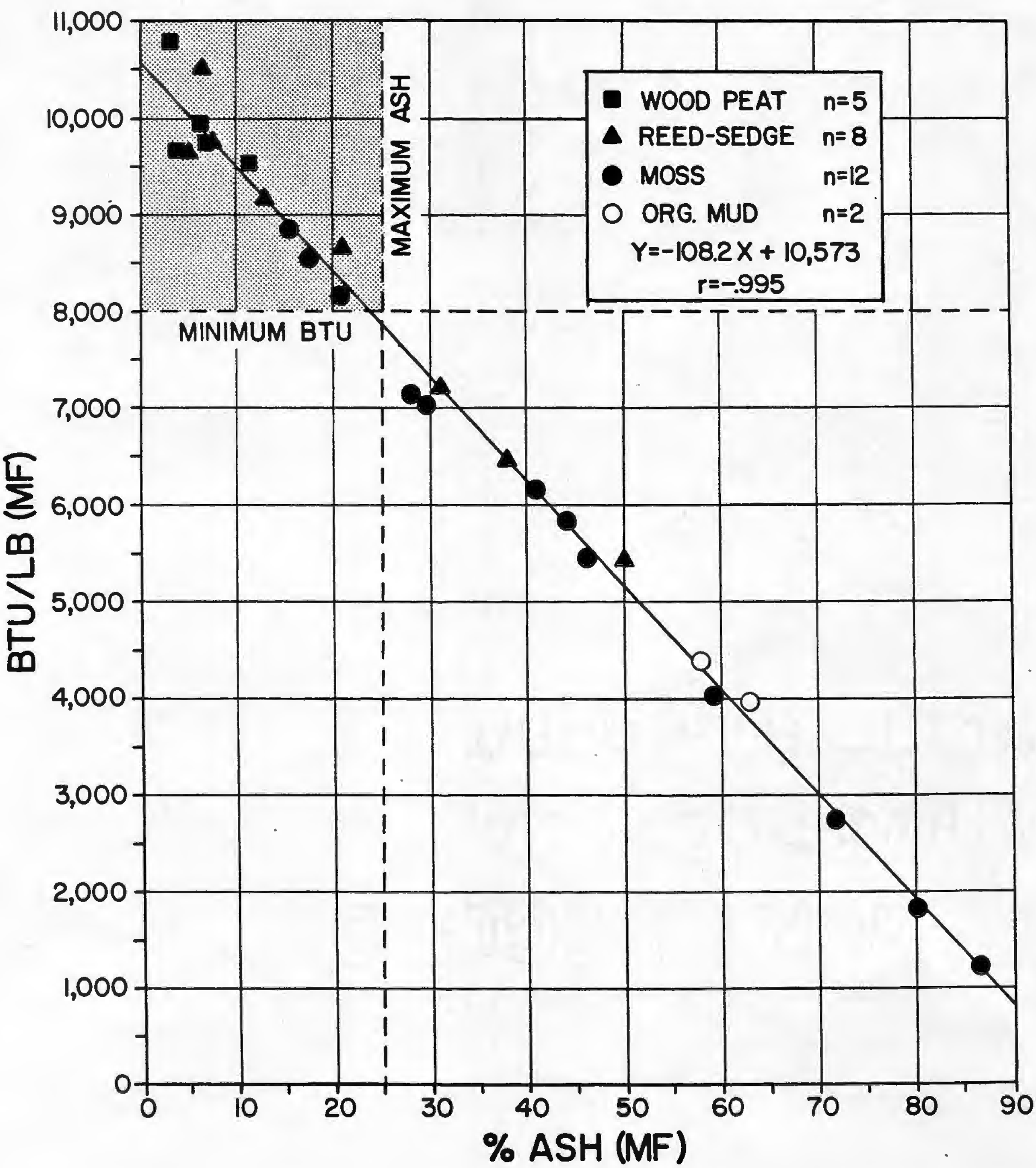
Ash, moisture and fiber content was determined for 299 peat samples. The results of these analyses are with the peat core logs (App. 2). Table 6 is a summary of the results by peat type. Sixty-eight samples of wood peat, 85 samples of reed-sedge peat, 100 samples of moss peat, and 46 samples of organic mud and sand were analyzed.

Wood peat has the lowest average ash content (7.1%) (Fig. 22), is intermediate in moisture content (86.0%) (Fig. 23) and has the lowest average fiber content (25.2%) (Fig. 24). Eight of the wood peat samples contained wood fragments greater than 2 cm (shortest axis) with an average wood content of 6.4%.

Ash content of reed-sedge peat varies widely

Fig. 20.--Relationship of calorific value (BTU/lb) and ash content in moisture free samples from Chapman Swamp. Shaded area contains fuel-grade samples.

BTU vs ASH CONTENT



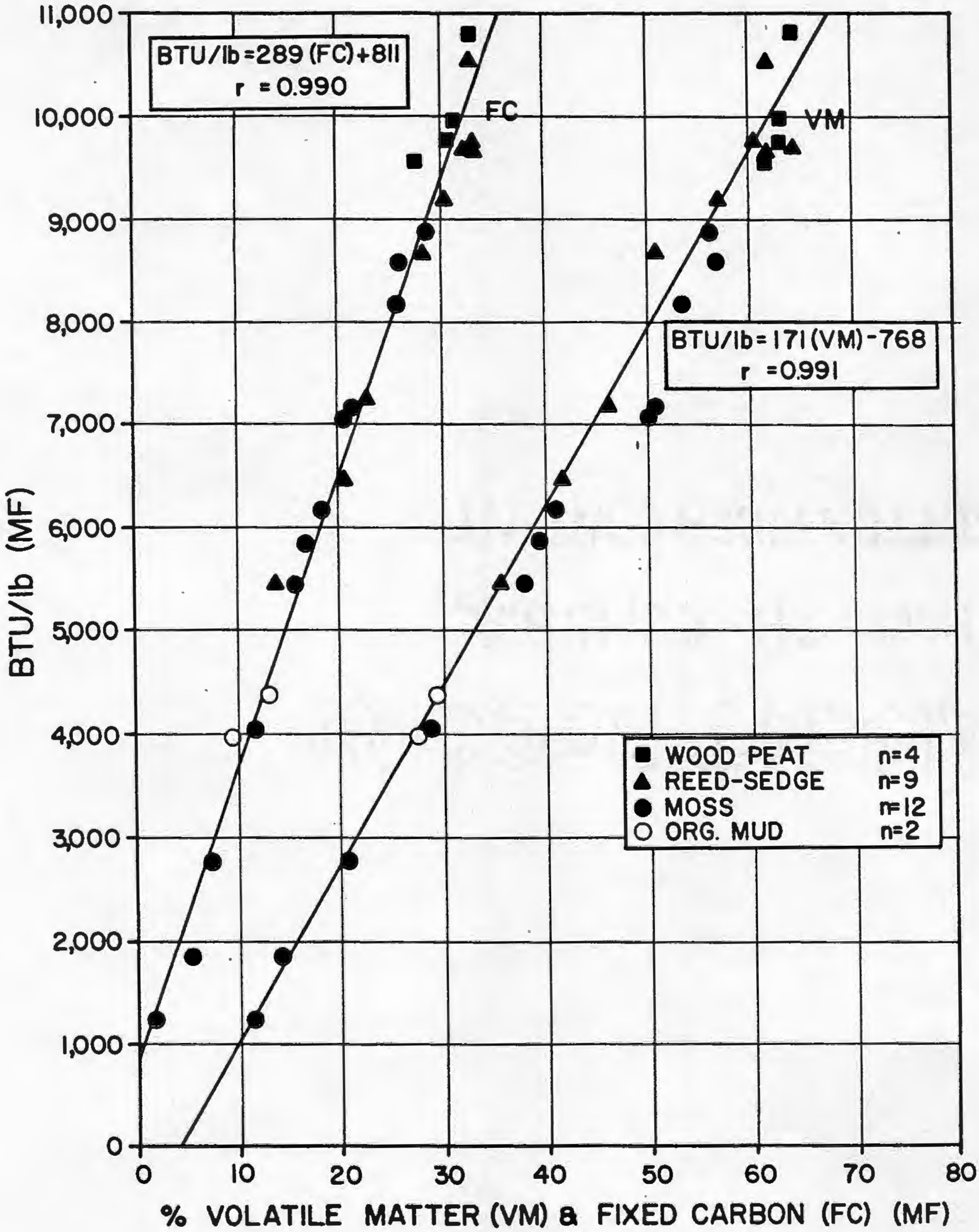

BTU/lb=289 (FC)+811
r = 0.990
FC
VM
BTU/lb= 171 (VM) - 768
r = 0.991
WOOD PEAT n=4
REED-SEDGE n=9
MOSS n=12
ORG. MUD n=2
BTU/lb (MF)
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0
10
20
30
40
50
60
70
80
% VOLATILE MATTER (VM) & FIXED CARBON (FC) (MF)

Table 6. -- Summary of Peat Resource Project (Dept. Geology, Univ. RI) ash, moisture and fiber analyses.

PEAT TYPE		% ASH (MF)	% MOISTURE (MF)	% FIBER (MF)
Wood n=68	Mean	7.1	86.0	25.2
	Max.	36.2	91.7	63.6
	Min.	1.8	71.3	1.3
Reed-sedge n= 85	Mean	18.9	85.0	31.7
	Max.	72.6	93.0	80.8
	Min.	3.2	34.1	0.8
Moss n= 100	Mean	31.0	88.2	31.7
	Max.	73.1	93.7	94.1
	Min.	0.3	61.8	5.6

Fig. 22.--Distribution of ash content of the three peat types, determined from Peat Resource Project (Dept. Geology, Univ. RI) analyses. Fuel-grade ash content limit is 25% (Davis, et al., 1980).

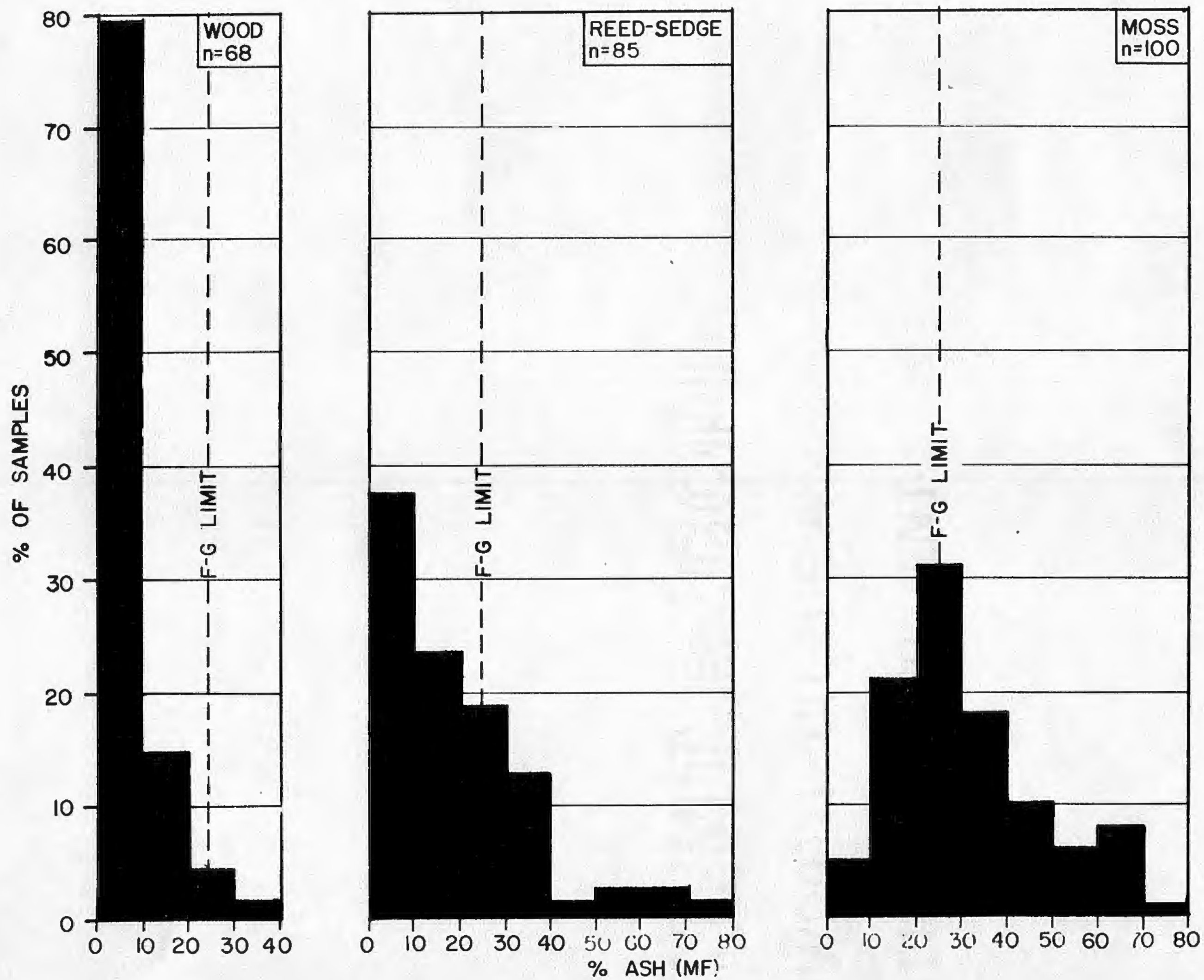
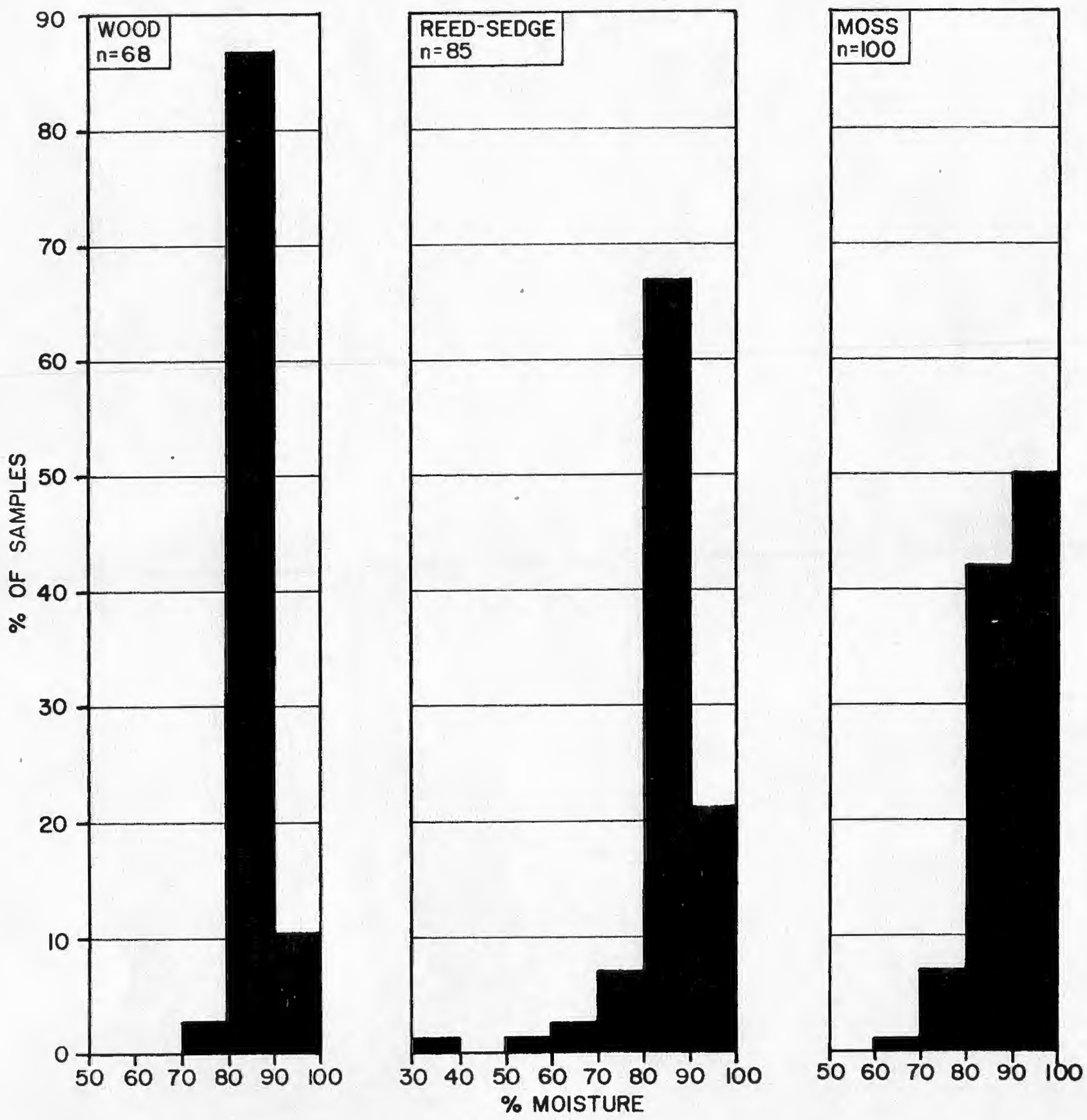
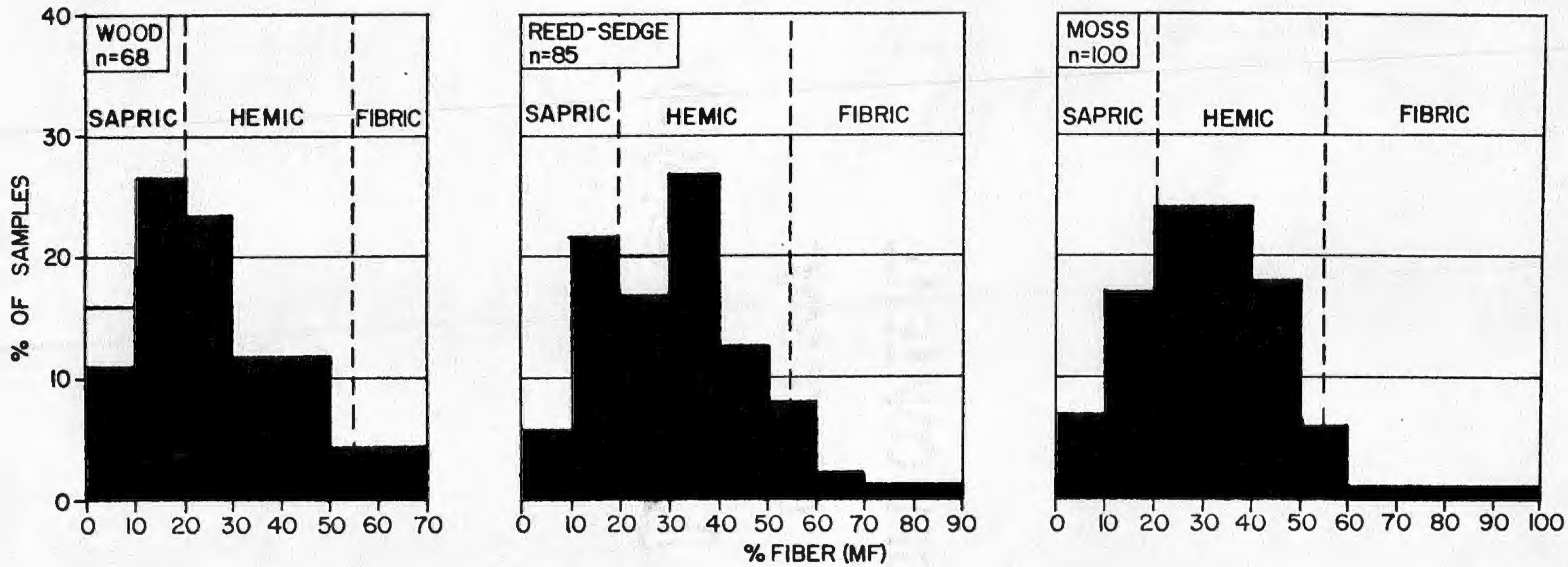

% OF SAMPLES
WOOD
n=68
REED-SEDGE
n=85
MOSS
n=100
F-G LIMIT
% ASH (MF)
0
10
20
30
40
50
60
70
80

Fig. 23.--Distribution of moisture content of the three peat types, determined from Peat Resource Project (Dept. Geology, Univ. RI) analyses.



WOOD
n=68
REED-SEDGE
n=85
MOSS
n=100
% OF SAMPLES
% MOISTURE
0
10
20
30
40
50
60
70
80
90
50 60 70 80 90 100
30 40 50 60 70 80 90 100
50 60 70 80 90 100

Fig. 24.--Distribution of fiber content of the three peat types, determined from Peat Resource Project (Dept. Geology, Univ. RI) analyses. Limits of decomposition classes are shown.



WOOD
n=68
SAPRIC
HEMIC
FIBRIC
REED-SEDGE
n=85
SAPRIC
HEMIC
FIBRIC
MOSS
n=100
SAPRIC
HEMIC
FIBRIC
% OF SAMPLES
0
10
20
30
40
0 10 20 30 40 50 60 70
0 10 20 30 40 50 60 70 80 90
0 10 20 30 40 50 60 70 80 90 100
% FIBER (MF)

(3.2-72.6%) (Fig. 22) and the average value of 18.9%. places it intermediate between the other two peat types. Reed-sedge peat has the lowest average moisture content (85.0%) (Fig. 23) and shares with moss peat the highest average fiber content (31.7%) (Fig. 24).

As with reed-sedge, the variation of ash contents is large in moss peat (0.3-73.1%) (Fig. 22) and the average ash value is the highest of the three peat types at 31.0%. Moss peat has the highest average moisture content (88.2%) (Fig. 23) and, as mentioned previously has a fiber content of 31.7% (Fig. 24).

Average fuel-grade ash, moisture and fiber contents were determined for each peat type using samples with less than 25% ash (Table 7). Using the average ash contents in the BTU vs ash regression equation (Fig. 20) an average fuel-grade calorific value for each peat type was determined (Table 8).

Bulk Density

From the twenty peat samples analyzed for bulk density (App. 2), thirteen with ash content less than 25% and one moss peat sample containing 28% ash were used to determine an average fuel-grade bulk density for each peat type (Table 7). Moss peat was the least dense with average bulk density of 0.092 g/cc or 0.142 g/cc air-dry. Reed-sedge was slightly denser at 0.121 g/cc or 0.186 g/cc air dry. Wood peat was most dense at 0.159 g/cc or 0.245 g/cc air-dry.

The determination of peat density is necessary to

Table 7. -- Summary of Peat Resource Project (Dept. Geology, Univ. RI), ash, moisture, fiber and bulk density analyses of fuel grade samples.

PEAT TYPE		% ASH (MF)	% MOISTURE (MF)	% FIBER (MF)	BULK DENSITY g/cc
Wood n= 67	Mean	6.7	86.0	25.5	0.159 (n=5)
	Max.	24.6	91.7	63.6	0.241
	Min.	1.8	71.3	1.3	0.125
Reed-sedge n= 61	Mean	11.8	85.4	33.5	0.121 (n=4)
	Max.	24.4	93.0	80.8	0.132
	Min.	3.2	34.1	2.9	0.112
Moss n= 40	Mean	16.8	90.0	42.0	0.092 (n=5)
	Max.	24.6	93.7	94.1	0.140
	Min.	0.3	72.5	5.6	0.048

Table 8. --Average fuel-grade heating values

Peat Type (n)	Mean Ash (%)	Mean BTU/lb (MF)
Wood (67)	6.7	9848
Reed-Sedge (61)	11.8	9296
Moss (40)	16.8	8755

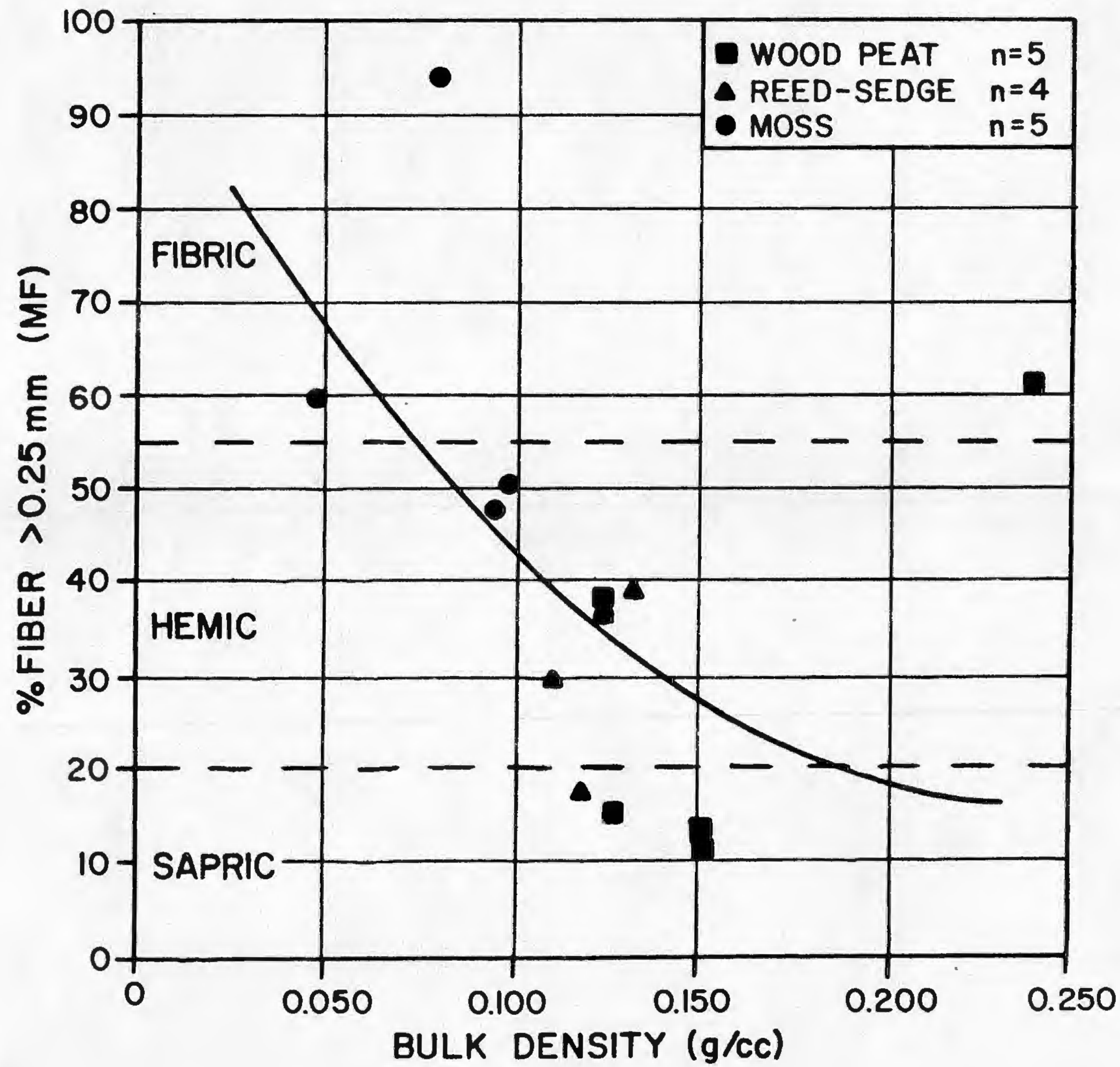
Regression Equation: BTU/lb (MF) = -108.2 (ash %) + 10,573 calculate the total energy resource in a wetland (Fox, et al., 1977; Otte and Ingram, 1980; Davis et al., 1980; Severson, et al., 1980). Direct determination by drying a known volume of peat is accurate but requires a large sample. Two indirect methods of determining bulk density with smaller samples use fiber (Boelter, 1969) and moisture content (Ingram and Otte, 1981a, b).

Boelter (1969) found a relationship between fiber content and bulk density in several fiber size fractions. The >0.25 mm fiber size fraction was chosen for comparison in this study because of the high coefficient of multiple determination (0.87) reported by Boelter (1969). Comparison of bulk density and fiber analyses of Chapman Swamp peat indicate a trend which generally follows the curve of Boelter (1969) (Fig. 25). The scatter of the data around the curve indicates that for the peat in this study the predictability of the relationship is not as good.

A linear relationship between moisture content and bulk density was used by Ingram and Otte (1981a, b) to extrapolate bulk density data over large areas where direct determinations were not done. Comparing data from Chapman Swamp with the line of Ingram and Otte (1981a, b) (Fig. 26) a similar general trend is seen but the scatter of the points is large.

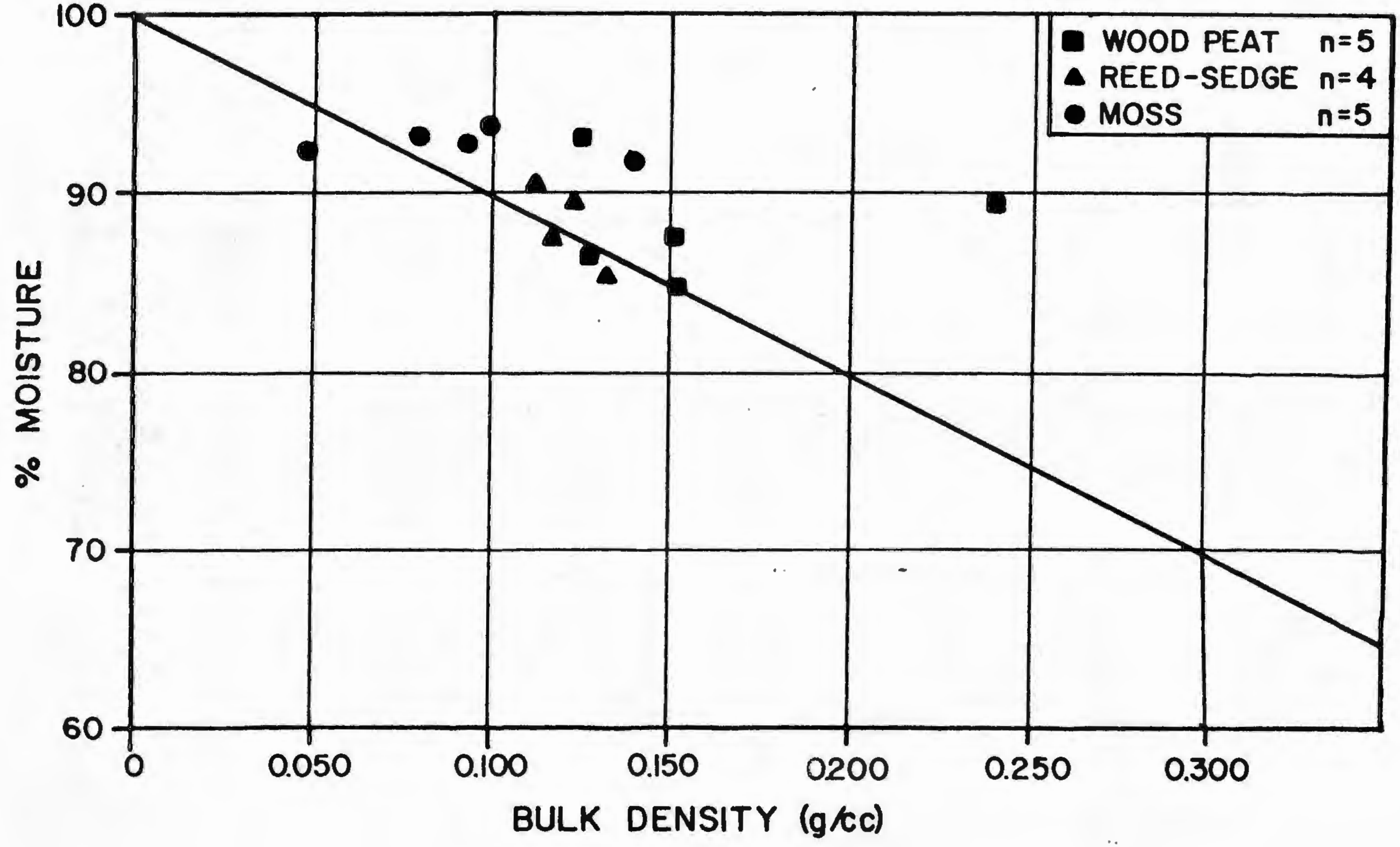
Possibly with more data from Chapman Swamp, a reliable relationship for predicting bulk density may be developed. The narrow range of bulk density results within each

Fig. 25.--Relationship of fiber content and bulk density of fuel-grade peat samples from Chapman Swamp compared with a curve derived by Boelter (1969) using peat from Minnesota.



WOOD PEAT n=5
REED-SEDGE n=4
MOSS n=5
FIBRIC
HEMIC
SAPRIC
%FIBER >0.25 mm (MF)
BULK DENSITY (g/cc)
0
10
20
30
40
50
60
70
80
90
100
0.050
0.100
0.150
0.200
0.250

Fig. 26.--Relationship of moisture content and bulk density of fuel-grade peat samples from Chapman Swamp compared with a linear relationship determined by Ingram and Otte (1981a, b) for peat from North Carolina.


% MOISTURE
100
90
80
70
60
0
0.050
0.100
0.150
0.200
0.250
0.300
BULK DENSITY (g/cc)
WOOD PEAT n=5
REED-SEDGE n=4
MOSS n=5

fuel-grade peat type (Table 6) indicates very little change in bulk density over the basin. A basin-average bulk density, based on several samples from throughout the wetland, is an accurate measure of the true peat density, so a predictive relationship is not necessary.

Peat Stratigraphy

Some general trends of the physical properties are seen in the peat stratigraphy (App. 2). Fiber and moisture content decrease down core whereas ash increases. The ash found in reed-sedge peat was sand and silt and easy to identify in the field. Moss peat contains ash of a finer grain size which was difficult to distinguish from the decomposed peat material.

The peat isopach contours (Fig. 27, 28, in pocket) indicate four peat sub-basins within the wetland basin. The largest of these is the west sub-basin, bounded to the west by RI 78 and the Westerly landfill, to the east by till-mantled bedrock and kame delta, to the north by RI 91, and to the south by the Charlestown Moraine. Traverse lines I,VI,XII,XIII, and XIV (Fig. 27) are in the west sub-basin. Stratigraphy in the sub-basin is characterized by basal reed-sedge peat in the western and southern parts of the sub-basin (cross-sections 4 and 5, Fig. 29, in pocket) and moss peat to the east and north (cross sections 2 and 4, Fig. 29). Moss peat makes up the surface peat layer beneath the pond and in the small bog at the southeast corner of the pond. Elsewhere in the basin, wood peat is at the surface.

Maximum peat thickness is 325 cm (Line VI, Fig. 27).

The southeast sub-basin could be considered an extension of the west sub-basin because of their connection at the southern end of the wetland (Fig. 27). This sub-basin is bounded to the north by Pound Road, to the south by the Charlestown Moraine complex, to the west by the "Island Trail" and to the east by a portion of kame delta. Traverse lines VII to X, XVI to XVIII and XXI criss-cross this basin. Cross-sections 5 and 6 (Fig. 29) show the basal stratigraphy across the entire sub-basin to be moss peat with wood peat at the surface under the forested wetland, reed-sedge peat at the surface under the broad-leaved deciduous shrub wetland, and surface moss peat under the broad-leaved evergreen and deciduous shrub wetland. The thickest peat accumulation in the sub-basin is 305 cm (Line XXI, Fig. 27).

The east basin is the main watercourse for drainage of the wetland. It is bounded on the south by Pound Road, on the north by the Pawcatuck River, on the east by kame delta and till-mantled bedrock and on the west by till-mantled bedrock and Pound Road. Traverse lines II to V, XI and XV (Fig. 27) cross this sub-basin. Cross-sections 3, 4 and 6 (Fig. 29) indicate basal reed-sedge peat with occasional moss peat lenses with surface peat types woody reed-sedge under the shrub wetland and wood under the forested wetland (Fig. 9). Maximum peat thickness in the sub-basin is 255 cm (line II, Fig. 27).

The northwest sub-basin is the smallest of the four sub-basins. It is bounded to the south by the Amtrack railroad tracks, to the west by an abandoned sand and gravel pit and on all other sides by till-mantled bedrock upland. Lines XIX and XX cross the sub-basin, the peat stratigraphy is characterized by basal reed-sedge peat overlain by wood peat (cross-section 1, Fig. 29). The maximum peat thickness in the sub-basin is 265 cm (line XX, Fig. 27).

Peat Volume and Tonnage

Total peat volume in the wetland, based on the peat isopach map, (Fig. 27) is 10,932,000 cubic meters. The fuel-grade limit in each core was determined by the uppermost occurrence of >25% ash. The thickness of peat above this limit in each core was designated the fuel-grade thickness and used to construct the fuel-grade isopach map with 1.5 m as the minimum contour (Fig. 28). Volumes were computed for each sub-basin (Table 9) and a total fuel-grade resource of 6,053,000 cubic meters was calculated.

To calculate the total energy potential of the in-situ peat volume, a determination of the average peat density and calorific value must be made. Since peat density and calorific value are variable, depending on the peat type, determination of the relative abundance of each peat type in a sub-basin is necessary. An estimate of the relative abundance of the fuel-grade peat types can be made by determining their relative areas in cross-section. For example, the fuel-grade peat section of traverse-line I

Table 9.--Fuel-grade peat volumes.

	SUB-BASIN VOLUMES (m^3)				
INTERVAL(m)	West	Southwest	East	Northwest	TOTAL
0-1.5	2,359,000	1,548,420	1,008,000	128,000	5,043,000
1.5-2.0	430,000	229,000	168,000	3,000	830,000
2.0-2.5	19,000	137,000		1,000	167,000
2.5+	13,000				13,000
Total	2,831,000	1,914,000	1,176,000	132,000	6,053,000

(cross-section 4, Fig. 29) is made up of 69% wood peat, 18% reed-sedge peat and 13% moss peat. After determining similar values for cross-section 5 across the west sub-basin an average abundance for each peat type was determined (Table 10). Applying these relative abundances to the appropriate average bulk densities and calorific values, estimates of average sub-basin values of both are obtained. This procedure was repeated for the southeast, east and northwest sub-basins using cross-sections 5, 3 and 1 (Fig. 29) respectively (Table 10).

Multiplying the bulk density value times the total fuel-grade peat volume yields fuel-grade peat tonnage (Table 10), from which air-dry tonnage can be calculated. Total fuel-grade peat in the entire wetland is 791,530 tonnes moisture free or 1,203,180 tonnes air-dry. Multiplying the sub-basin calorific value by the peat tonnage yields the total energy value of the fuel-grade peat in the sub-basin (Table 10). The total energy value of the fuel-grade resource in the entire basin is 7.372 Billion BTU.

Forest Resource

Clearing the forest from the peat surface is prerequisite to harvesting the peat in a forested wetland. In Chapman Swamp this includes 346 ha of maple and 132 ha of cedar (Table 4). Recent research at the University of Rhode Island Department of Forest and Wildlife Management has led to the development of a formula for cord-wood estimation in maple swamps (Mark Braiewa, pers. comm., May 1982). Using

Table 10.--Fuel-grade peat resource determination.

SUB-BASIN	% WOOD	% REED-SEDGE	% MOSS	SUB-BASIN AVERAGES DENSITY	SUB-BASIN AVERAGES BTU/lb (MF)		SUB-BASIN TOTALS TONNES (MF)	SUB-BASIN TOTALS BILL.BTU
West	71.1	22.3	6.6	0.146	9653		413,326	3.989
Southeast	15.2	5.3	79.5	0.103	8950		197,142	1.764
East	32.9	58.8	8.3	0.131	9433		154,056	1.453
Northwest	34.0	66.0	0.0	0.134	9483		17,554	0.166
						TOTAL	791,530	7.372

12.7 cm (5 inches) as an estimate of average dbh (diameter at breast height) for the maples in the swamp, one hectare will yield 81.5 cords of wood. The following assumptions were used: (1) one cord equals 1154 kg at 20% moisture; (2) a specific gravity of 0.51; and (3) 80 cubic feet of solid wood per cord. A similar estimate for cedar forest is not available.

DISCUSSION

Paleogeography

The stratigraphic relationships of facies Gm, Sl, and Sli in the Crandall sand and gravel pit (stratigraphic sections 1, 9, Fig. 4, in pocket) represent medial alluvial fan (delta-plain) prograding over delta front (Fig. 5). The existence of facies Fr, Fl, and Flc at stations 3, 4a, 4b, 6 and 7 (Fig. 4, in pocket) represent deposition on the pro-delta slope between pre-existing delta lobes. The sediment transport mechanism in the pro-delta slope environment is turbidity flows along the lake bottom creating ripple-drift cross-stratification at the base of the section followed by progressively lower energy sedimentary structures as the flow subsides completing the sequence with a laminated silt drape (Ashley, 1975). This sequence can be rejuvenated at any time by initiation of subsequent turbidity flows. In an ideal situation the sequence is carried to conclusion when clay-rich laminae are deposited during the winter months. When a couplet of fine sand and silt with clay-rich silt occurs it represents one year of deposition and is called a varve.

Proximal varves are characterized by thick sand and silt layers and thin clay-rich laminae (Ashley, 1975). In distal lake-bottom environments the sand and silt layer becomes less dominant with distance from the sediment source. The vibracore from Chapman Pond (VC-2, Fig. 2) was disturbed in transport, destroying all sedimentary structures except the basal 160 cm of facies Fl and Flc (Fig. 4, in pocket, 8). The thin Flc laminae in the vibracore suggest a distal lake bottom depositional environment; the top of the distal varve sequence is at an elevation of 3.2 m and the base of the varves was not penetrated. The grain size of the sediment in the other 530 cm of the core is similar to facies Fl and Fr, suggesting pro-delta slope prograding over distal lake bottom.

The vibracore taken in the pit (VC-1, Fig. 4) contains fining-upward sequences of facies Gmc, Gmpg, and Sl which are interpreted as middle alluvial fan facies. The position of these facies below the kame delta sediments indicates deposition occurred before the lake existed, that is, before the ice retreated. Consequently, the stratigraphy represents deposition in a sub-ice tunnel, the stacked fining-upward sequences represent pulses in meltwater discharge.

The relationship of the sediments observed in the pit and beneath the pond are indicative of a kame delta depositional system. The ice-contact nature of the delta is indicated by the upper alluvial fan facies in stratigraphic section 1 (Fig. 4) and a flow till exposure 10 m west of section 1.

Figure 30 is an interpretation of the paleogeography of the area during deposition of sequence 2 (Schafer, 1965, 1968). The first passive ice front established by the glacier after receding from the Charlestown Moraine formed an ice-dam creating Glacial Lake Chapman (Fig. 30A). Three sediment sources were active along the ice-front at this time, depositing three kame deltas. As the ice front continued to recede, the western sediment sources had sporadic discharge but the eastern source remained active, creating a continuous kame delta along the eastern shore of the lake. Figure 30B is the paleogeography during early deposition of sequence 2b. The central and western sediment sources were active, depositing two small kame deltas. The Crandall sand and gravel pit is in the central part of this delta (Fig. 4 (in pocket), 28B). The delta-plain and delta-front facies at stratigrapy stations 1 and 9 were deposited at this time followed by progradation of a third delta lobe into the interlobate bay. The pro-delta slope sediments at the other exposures in the pit represent the third delta lobe. The facies in the vibracore from the pit (VC-1, Fig. 4), indicate an active ice-tunnel supplying sediment to the portion of the kame delta south of the pit.

A second passive ice front of sequence 2b was

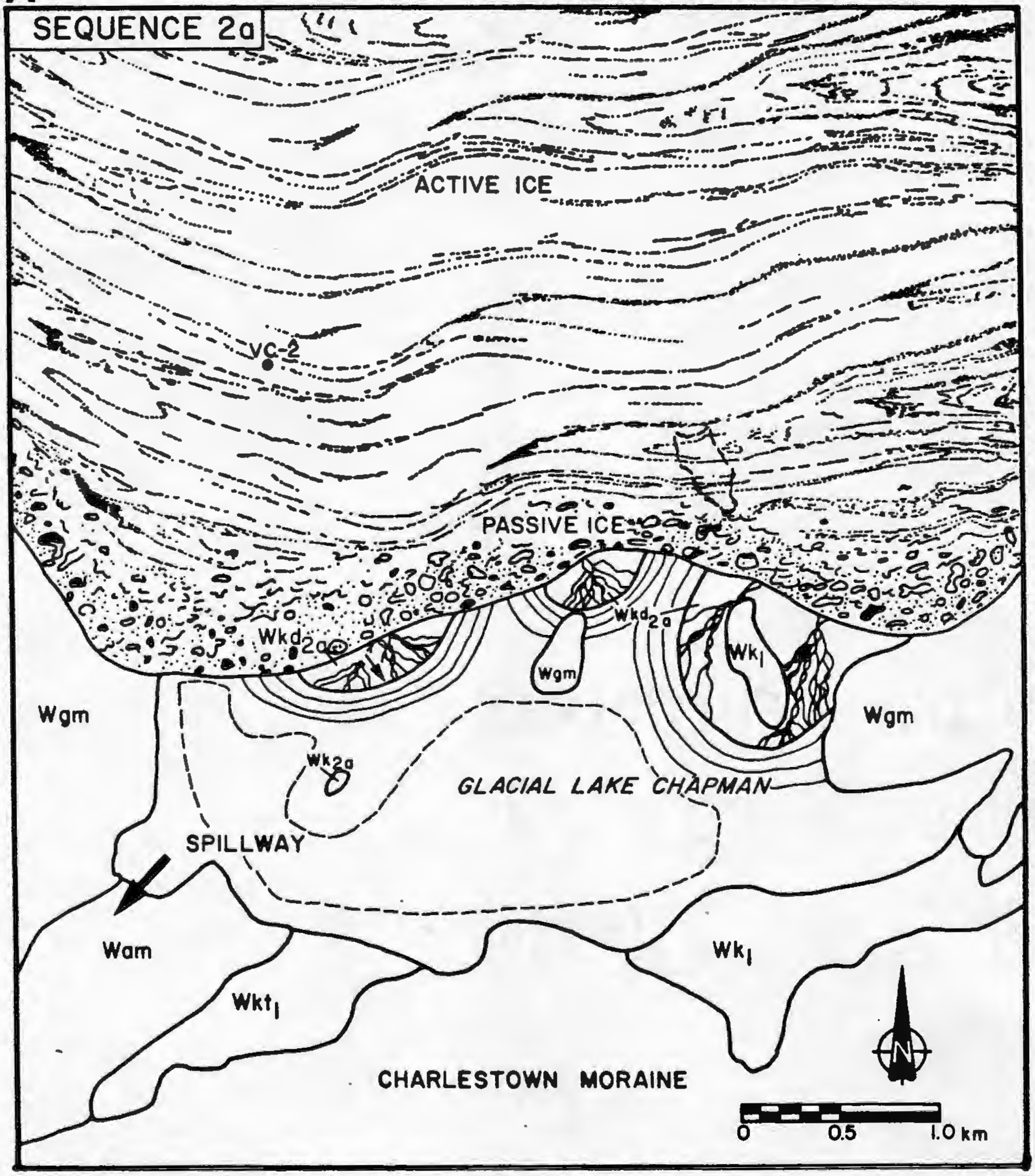
Fig. 30.--Paleogeography of the Chapman Swamp area during deposition of sequence 2 (Fig. 2, in pocket). Note Crandall sand and gravel pit outlined on east side of lake, and vibracore 2 on west side. Paleocurrent data outside of pit was collected by Schafer (1965, 1968).

A.--Sequence 2a

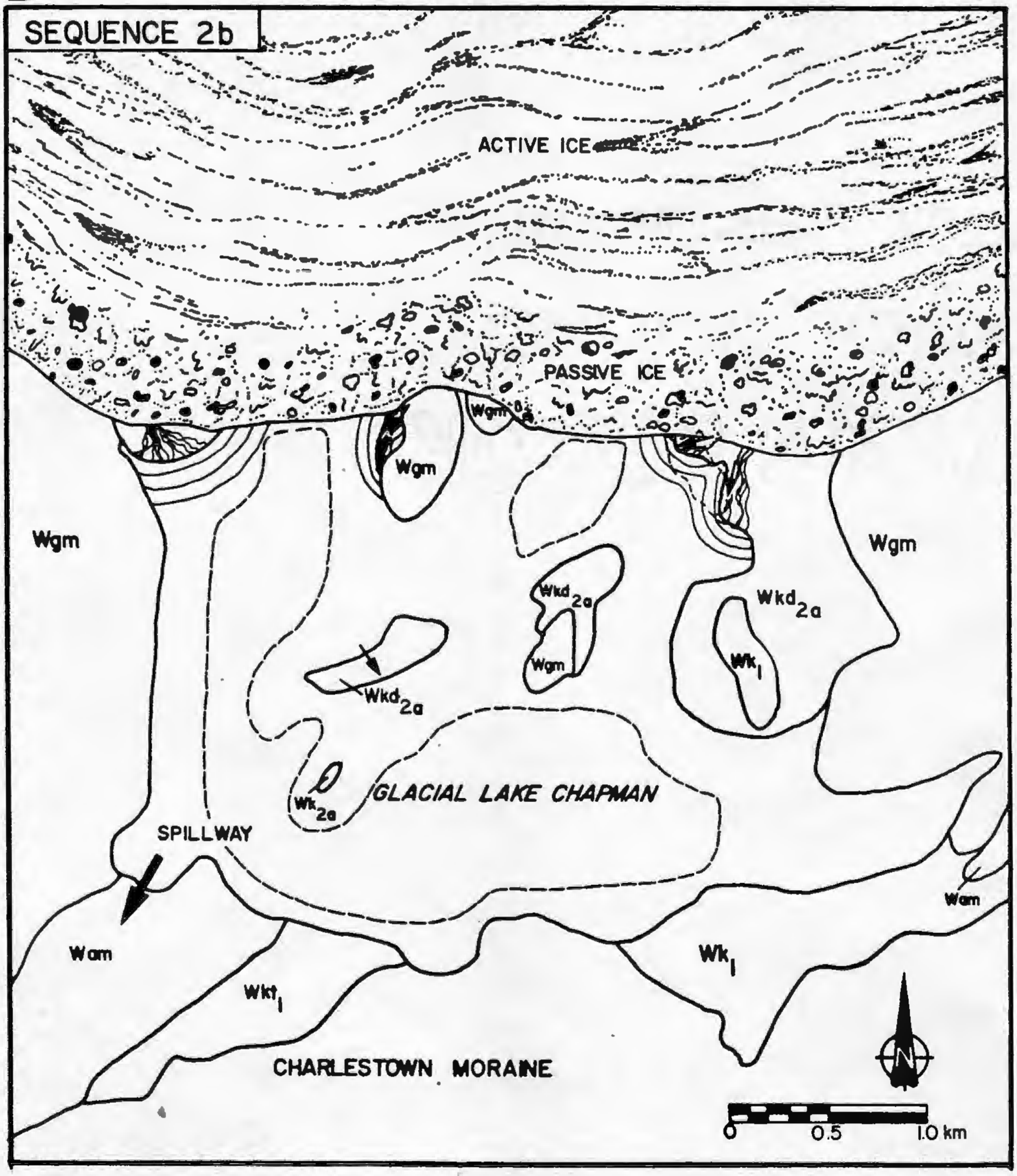
B.--Early sequence 2b

C.--Late sequence 2b

A

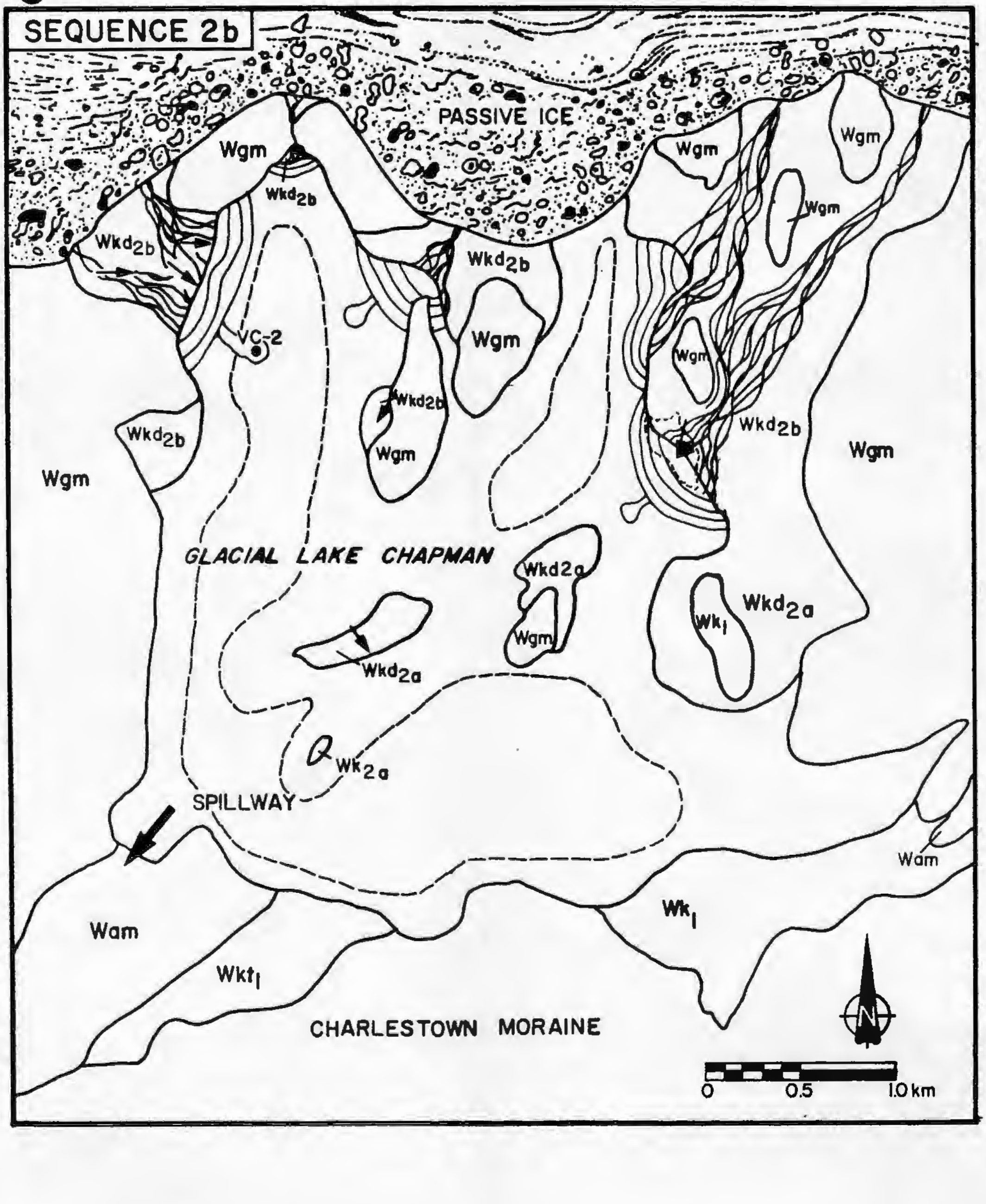

SEQUENCE 2a
ACTIVE ICE
VC-2
PASSIVE ICE
Wkd2a
Wkd2a
Wgm
Wk1
Wgm
Wgm
Wk2a
GLACIAL LAKE CHAPMAN
SPILLWAY
Wam
Wkt1
Wk1
N
CHARLESTOWN MORAINE
0
0.5
1.0 km

B



SEQUENCE 2b
ACTIVE ICE
PASSIVE ICE
Wgm
Wgm
Wgm
Wgm
Wgm
Wkd 2a
Wkd 2a
Wkd 2a
Wk 1
Wk 2a
GLACIAL LAKE CHAPMAN
SPILLWAY
Wam
Wam
Wkt 1
Wk 1
CHARLESTOWN MORAINE
0
0.5
1.0 km
N

C


SEQUENCE 2b
PASSIVE ICE
Wgm
Wkd2b
VC-2
GLACIAL LAKE CHAPMAN
Wkd2a
Wk1
Wk2a
SPILLWAY
Wam
Wkt1
CHARLESTOWN MORAINE
N
0
0.5
1.0 km

established at the present location of the Pawcatuck River and the western sediment source became reactivated, depositing the kame deltas in the northwestern corner of the study area (Fig. 30C). The distal varve facies in the vibracore from Chapman Pond (VC-2, Fig. 8, 28C) represent deposition before the western source was reactivated; the overlying disturbed sediments represent the prograding pro-delta slope.

The lake remained in the basin, expanding to the north with the receding ice-front until it was dammed by deposition of sequence 3 (Fig. 2). Lake drainage occurred when headward erosion caused a breach through the sequence 3 deposits establishing drainage along the present course of the Pawcatuck River. As lake level fell, the basin was divided into a number of smaller basins where peat accumulation began.

The delta-plain, delta-front contact in the pit is at 15.5 m elevation, and water depth in braided streams is approximately 1.5 m (Boothroyd and Ashley, 1975) indicating a lake level of 17.0 m. The present-day elevation of the lowest outlet, at the southwest corner of the basin, is 13.7 m. The difference in elevation is probably due to collapse of the ablation moraine (Wam, Fig. 2, 28) as buried ice melted.

The large (>200 ha), shallow (<5 m) basin of glacial lake origin is one end member of a continuum of relationships between peat resources and glacial environments. Great, Indian Cedar, and Watchaug Swamps are other examples of peat-filled glacial lake basins in Rhode Island. The other end member is small (,20 ha) deep (¢5 m) basins that originated as ice-molds-in-till, examples of which are found on Block Island (Peters, 1981) and kettle holes, such as Factory Pond (work in progress, URI Department of Geology). Intermediate environments include steep-walled, till-mantled bedrock valleys (Dawley Swamp), meltwater channels (Franklin and Great Swamps, Block Island) and swales on outwash plains (Mishnock Swamp). These relationships can be used in peat prospecting to identify potential resources based on associated glacial environments.

Depositional Environments of Peat

As mentioned previously, wetland type (depositional environment) is the one factor controlling the peat type being deposited. Ash content, a reliable indicator of peat fuel-value (Fig. 20) is also controlled by depositional environment (Peters, 1981). Reliable predictions of fuel value based on peat type would be helpful in preliminary evaluation of peat resources.

The consistently low ash values in wood peat is a result of a lack of terrigenous sediment influx from surface streams in the forested wetland environment. This generalization is true throughout Chapman Swamp and could be extrapolated to other forested wetlands lacking surface streams.

The large variation in ash content in reed-sedge peat (Fig. 22) has been noted in other studies (Boothroyd, et al., 1979; Peters, 1981) and is a reflection of the proximity of the peat-forming environment to surface water transporting terrigenous sediment. The Scrub-Shrub and Emergent wetlands traversed by line V and adjacent to the river (Fig. 9, 25, in pocket) are areas innundated by overbank flow during flood events in the Pawcatuck and tributary streams.

Recent prolonged rain (June 4 to 7, 1982) caused flooding of the river. Water in the two drainage pipes passing under RI 91, normally flow north toward the river, but on June 6, 1982 water was flowing south across the road surface at approximately 20 cm/sec, and suspended sediment was visible in the water. Further south of the river, the effects of flooding were reduced. The section of Pound Road that runs east-west was flooded with south-flowing water, but flow was barely discernible and no suspended sediment was observed. Consequently, surface peat near RI 91 is now rich in terrigenous sediment and the southern limit of contamination is somewhere between RI 91 and Pound Road.

The depositional environment of moss peat is typically an area of stagnation with little or no nutrient influx (Daubenmire, 1968) and no terrigenous sediment influx, creating a low ash peat. Previous peat resource investigations have found moss peat to be consistently fuel-grade (Boothroyd, et al., 1979; Davis, et al., 1980;

Severson, et al., 1980; Peters, 1981). The wide range of ash content in moss peat of this study (Fig. 22) is perplexing. The surface moss peat in the southeast sub-basin has low ash values (core VII-E, App. 2). Elsewhere, the moss peat samples are from the base of the peat section and have high ash contents (core I-H, App. 2). The existence of moss peat at the base of a peat deposit has not been reported in previous studies of peat stratigraphy (Dachnowski, 1924, 1926; Heinselman, 1963, 1970; Moore and Bellamy, 1967; Cameron, 1970a, b, 1975; Boothroyd, et al., 1979; Severson, et al., 1980; Peters, 1981).

The simplest explanation of the high ash content in a nutrient-poor environment is that terrigenous sediment was transported by low-nutrient surface water. Such a situation is not seen in the modern moss-forming environment. A second hypothesis is the terrigenous sediment was introduced to the environment by eolian transport of silt and fine sand from glacial outwash before upland vegetation stabilized sediment during the early Holocene. The eolian mantle of silt and sand covering glacial sediments in southern New England is an example of deposition by this process (Schafer and Hartshorn, 1965). Credence is added to this argument by the fact that ash in the moss peat is silt and clay size, whereas ash in reed-sedge peat is typically sand, suggesting fluvial transport.

Tundra was the first plant community to become established after deglaciation on Block Island (Sirkin, 1976). A similar biota is assumed for the Chapman Swamp area when the proposed eolian transport was occurring. Mosses are common plants in arctic tundra environments (Steere, 1965), but verification of the genus of the moss is necessary to make specific inferences concerning their existence in environments subject to terrigenous sediment influx.

Eolian transport and deposition of silt and sand is occurring in recently deglaciated areas of Alaska today (J.C. Boothroyd, pers. comm.) suggesting a possible modern analog of the Chapman Swamp stratigraphy. Wet sites in the tundra of the Prudhoe Bay region of Alaska are dominated by emergent wetland (reed-sedge) environments (Walker, et al., 1980). Consequently, the Prudoe Bay region is not a good modern analog for deposition of high ash moss peat. However, the muskeg of sub-arctic and temperate environments may be a modern analog. Microscopic analysis of the peat to determine the moss species, analysis of the pollen stratigraphy, carbon dating of the peat, and further study of peat-forming environments in recently deglaciated areas are recommended as the next steps in identifying the depositional environment of high-ash moss peat.

Peters (1981), proposed two paths of wetland development based on peat stratigraphy in Block Island wetlands. Hydroseral succession (Daubenmire, 1968; Moore and Bellamy, 1974) begins with submergent and floating-leaved plants in an oligotrophic (oxygen-rich, nutrient-poor) pond or lake and is represented by basal aquatic (sedimentary) peat in the stratigraphy. This initial stage is followed by colonization by emergents, mosses, and eventually woody plants as the peat substrate is built up and basin filling progresses from the periphery towards the center. Paludification is the process of wetland expansion from a central area due to the water holding capacity of peat restricting drainage and causing a rise in water levels (Heinselman, 1963, 1970).

The lack of aquatic peat in Chapman Swamp suggests that the initial stage of hydroseral succession did not occur in the basin. The basal moss and reed-sedge peat suggests that initial communities of mosses and emergents became established in shallow depressions which expanded over the basin by paludification. Succession continued on the expanding wetland surface, and is an active process today.

Snuggedy Swamp of South Carolina is a modern peat-forming environment situated in a non-glaciated area. The swamp basin is a back-barrier environment that has been invaded by a freshwater wetland (Staub and Cohen, 1978). The swamp is truncated by the Ashepoo and South Edisto Rivers, which periodically breach natural levees causing splay deposition of terrigenous sediment over large areas of the peatland. The surface vegetation is similar to that seen in Chapman Swamp as is the total thickness of peat. The peat in Chapman Swamp is probably of an overall higher quality than that in Snuggedy Swamp because of the lack of large volumes of terrigenous sediment influx from the controlled flow of the Pawcatuck River.

Dismal Swamp of Virginia and North Carolina is another example of modern peatland development on the coastal plain. The peat fills basins which are remnants of river channels and lakes on the Pleistocene surface (Ingram and Otte, 1981b). The swamp is not crossed by major rivers and terrigenous sediment influx is concentrated around the wetland margins and is negligible toward the center of the deposits. The Dismal Swamp peat is similar in quality to Chapman Swamp peat, reflecting the lack of widespread terrigenous sediment influx in both peatlands. A major difference between the peatlands on the coastal plain and those in Rhode Island is one of magnitude; the coastal plain peatlands cover 1 to 18 times the area of Chapman Swamp.

Resource Utilization

Each of the four peat sub-basins contains a potentially useful energy resource (Table 10). The west basin contains the largest contiguous resource, is adjacent to an already disturbed area (landfill), and contains a large bonus resource of maple firewood. Consequently, the west sub-basin is suggested as a high priority harvest area.

The proposed harvest area is within the 1.5 m isopach on the fuel-grade peat isopach map (Fig. 28). The total fuel-grade peat resource in the area is 680,000 tonnes, and the maple trees covering the area represents 12,800 cords of wood (81.5 cords/ha, 167 ha). It should be kept in mind that although fuel-grade peat outside of the 1.5 m contour does not meet the Department of Energy thickness minimum, it would add to the resource if the harvest area were expanded.

A hydraulic harvesting technique is recommended to eliminate the need to drain the wetland and possibly affect the surrounding water levels (Davis and White, 1979). The upland island at the southwest crook in Pound Road could serve as a draining and drying area for the harvested peat.

Two alternative uses for the peat and wood are proposed: (1) use for home heating in wood stoves and furnaces and 2) use as fuel to generate electricity.

The average home burning wood as a primary heat source in Rhode Island uses 5.25 cords of wood per year (Stoddard, 1979). The 12,800 cords of wood in the proposed harvest area could supply the heating needs of 1000 homes for 2 years.

The fuel-grade peat in the west basin is 79% as efficient as dry wood (7950 BTU/lb)(Parsons, 1978). Assuming one cord of wood weighs 1.95 tonnes (Parsons, 1979) the fuel-grade peat resource is equivalent to 255,400 cords of wood or 50 years of heat for 1000 homes.

At this time, the Narragansett Electric Co. supplies electricity to the community of Westerly from a regional power grid (D. Hartley, Rhode Island Public Utilities Commission, pers. comm., May 1982). Total electrical usage in the town for the year ending Dec. 31, 1980 was

102,500,176 KWH (Narragansett Electric, 1981). Until 1977 some of the power used by the residents of Westerly was generated at a diesel-fueled 3-MW power plant on the north bank of the Pawcatuck River in Hopkinton (Fig. 28) (W. Kimball, Narragansett Electric, pers. comm., May 1982). At full capacity, a 3-MW plant could have supplied 26% of the 1980 electricity usage in Westerly. The site of the plant is presently abandoned so a new peat-fueled power plant could be constructed at the same location. A 3-MW power plant fueled by west sub-basin peat (average calorific-value 6274 BTU/lb, air dry, Table 8) would burn 13,900 tonnes (15,330 tons) (J. Peccararo, U.S. Department of Energy, pers. comm., July 1982). At this rate the peat in the sub-basin could supply the power plant for 45 years.

The initial cost of peat-fueled power plants is higher than for plants using conventional fuels (Ekono, 1977). The fact that peat fuel availability would not be subject to international politics or affected by high transportation costs makes peat an attractive alternative fuel. Detailed economic and environmental analysis of the entire peat harvesting, drying, transporting, burning and energy distribution process needs to be carried out to determine the feasibility of such a plant.

CONCLUSIONS

1) Identification of facies representing delta-plain, pro-delta slope and distal lake-floor depositional environments indicate a glacial lake origin of the Chapman

Swamp basin.

2) Hydroseral succession, causing variation in surface plant communities and paludification, causing expansion of the wetland over the entire basin; are major factors in peatland development in Chapman Swamp.

3) Chapman Swamp is a 685 ha freshwater wetland complex. Seventy percent of the wetland area is forested, 17.9% is scrub-shrub, 7.0% is aquatic bed, and 1.3% is dominated by emergent plants.

4) Three botanical peat types were identified in the wetland: wood, reed-sedge and moss. The most common stratigraphic relationship is wood peat over moss or reed-sedge peat.

5) Peat decomposition classes are defined for >0.25mm fiber size as: sapric, <20%; hemic 20% to 55%; and fibric >55%.

6) Maximum and average peat thicknesses in the basin are 325 cm and 160 cm, respectively. Maximum fuel-grade peat thickness is 300 cm.

7) Total volume of peat in the basin is 10,932,000 cubic meters, 6,053,000 cubic meters of which is fuel-grade.

8) Wood peat has the highest mean fuel-grade calorific value (9848 BTU/lb (MF)), reed-sedge peat is second highest (9296 BTU/lb (MF)) and moss peat is lowest (8755 BTU/lb (MF)).

9) The total fuel-grade peat resource is 1,203,180 tonnes (air dry), and the total energy resource represented

by the fuel-grade peat is 7 billion BTU.

10) Wood peat is consistently fuel-grade. Fuel value of reed-sedge peat is a function of exposure of the peat to fluvial activity. The modern moss peat environment contains fuel-grade peat, but eolian activity in the early Holocene contaminated the basal moss peat.

11) The west sub-basin is the recommended harvest area. The fuel-grade peat in the sub-basin could supply the fuel to produce more than 20% of the electricity needs of the town of Westerly for 45 years (based on 1980 usage). The combination of the peat and wood resource could supply the fuel for 1000 homes heated by wood stoves for 50 years.

12) The existence of a significant peat resource in a glacial lake basin is a beginning in the understanding of the relationship between peat resources and glacial environments in southern New England.

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APPENDIX 1:

Laboratory Methods

This step by step description of laboratory methods used for peat analysis is based on methods outlined by Boelter (1969), the American Society of Testing and Materials (1978), and Otte and Ingram (1980).

Equipment required: 1. Muffle furnace (temp. range to 550°C). 2. Convection oven (temp. range to 105°C). 3. Mettler balance. 4. Three-beam or digital balance with accuracy to 0.01 g. 5. 100 ml beakers. 6. Evaporating dishes. 7. Sieve (0.10, 0.15 or 0.25 mm). 8. Sodium hexametaphosphate (calgon).

MOISTURE AND FIBER DETERMINATION

1. Remove 100 g of sample from each section of core to be analyzed. A minimum density of one sample per meter of core is advised, more samples should be taken if the stratigraphy is complex.

2. Store samples in air-tight containers until ready to begin analysis, refrigerate if possible.

3. Split sample into two approximately equal parts. Place one of the samples in a 100ml beaker and the other in an evaporating dish. Weigh each container and determine the bulk weight of the samples.

4. Fill the beaker with a 5.0% Calgon (sodium hexametaphosphate) solution to aid in dispersion and place the evaporating dish in the oven at 105°C.

5. After 16 hours:

A. Wash the sample which has been soaking through a 0.10, 0.15 or 0.25 mm sieve to remove the finer fibers and completely decomposed material. Caution must be exercised to prevent abrasion of the fibers. Remove any wood fragments with largest dimension 2 cm or greater from the fiber and place in another beaker. Discard any mineral material retained in the sieve. Return the fiber to the original beaker and place the fiber and wood in the oven at 105°C for 16 hours.

B. Remove the evaporating dish from the oven and determine a dry weight of the sample. Save the sample in an air-tight container for future ash analysis.

Calculate the moisture content of the dried sample (Eq. 1) and the dry weight of the bulk fiber determination sample (Eq. 2).

$$\frac{BW-DW}{BW} \times 100 = \%Moisture \qquad \text{(Eq. 1)}$$

$$\frac{\%Moisture}{100} \times BWF = EWF \qquad \text{(Eq. 2)}$$

BW = bulk weight of moisture determination sample (g)
DW = dry weight of moisture determination sample (g)
BWF = bulkweight of fiber determination sample (g)
EWF = estimated dry weight of fiber determination sample (g)

6. After 16 hours of drying remove the fiber and wood samples from the oven, let cool, and determine their weights. Calculate the fiber and wood content using Equation 3.

$$\frac{DFDW}{EWF} \times 100 = \%\ \text{Wood or Fiber} \qquad \text{(Eq. 3)}$$

DFDW = Dry weight of fiber or wood (g)
EWF = estimated dry weight of fiber sample (Eq. 2).

ASH ANALYSIS

1. Weigh approximately two grams of the dry moisture determination sample into an incineration crucible using the Mettler balance, record the weight to .0001 grams.
2. Place the crucible in the muffle furnace making a diagram of the sample locations, any markings on the exterior of the crucible will be burned off. Set the furnace at 550° C and burn for 1 to 2 hours after the temperature in the furnace has stabalized. Some form of ventilation is needed during this part of the analysis to remove smoke from the room. Do not open the furnace door during the first 30 minutes, additional oxygen will cause a flare-up which could cause sample loss.
3. After the sample is completely incinerated remove it from the furnace and let cool (30 minutes). Weigh the sample and the crucible and then the crucible alone and subtract to determine the ash weight. Now the moisture-free ash content of the sample can be calculated (Eq. 4).

$$\frac{AW}{DTG} \times 100 = \%\text{Ash} \qquad \text{(Eq. 4)}$$

DTG = Dry two gram sample weight (g)
AW = Weight of ash (g)

BULK DENSITY

The core segment selected for bulk density analysis should be a representative sample of the peat type, it should be fuel grade, and a minimum of 10 cm long.

2. Place the entire core segment in a large evaporating dish or beaker and deterimine a bulk weight. Place the sample in the oven at 105 °C for 24 to 48 hours until completely dry. Determine the dry weight and calculate the bulk-density (Eq. 5) and the moisture content (Eq. 1).

$$\frac{DW}{VOL} = \text{Bulk Density (g/cc)} \qquad \text{(Eq. 5)}$$

DW = Dry weight of sample (g)
VOL = Volume of sample (cc)

Moisture, ash and fiber results should be reported to the nearest 0.1% and bulk density to the nearest 0.001 g/cc.

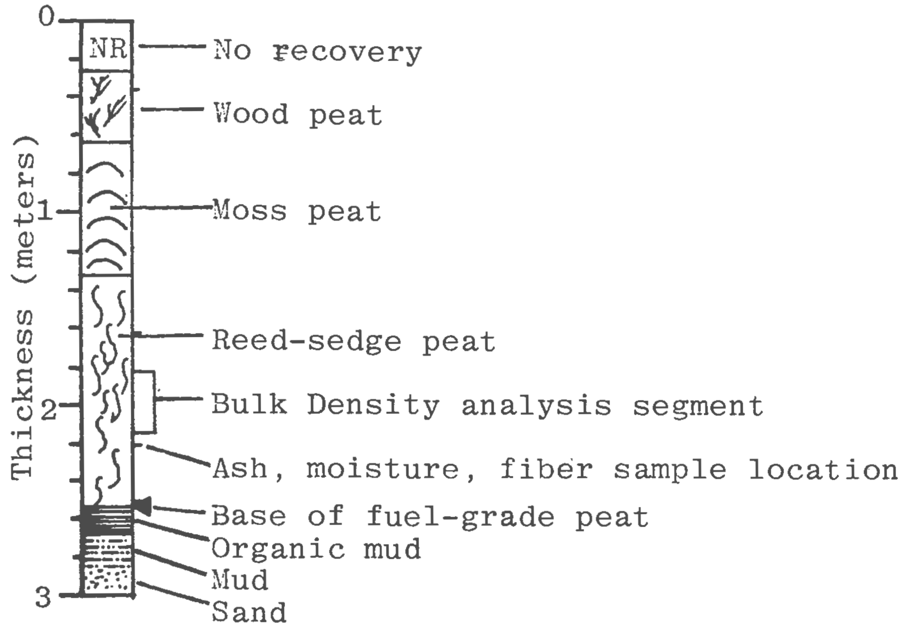
APPENDIX 2:

Peat Core Logs

Core Log Explanation

* —— Fuel analysis performed

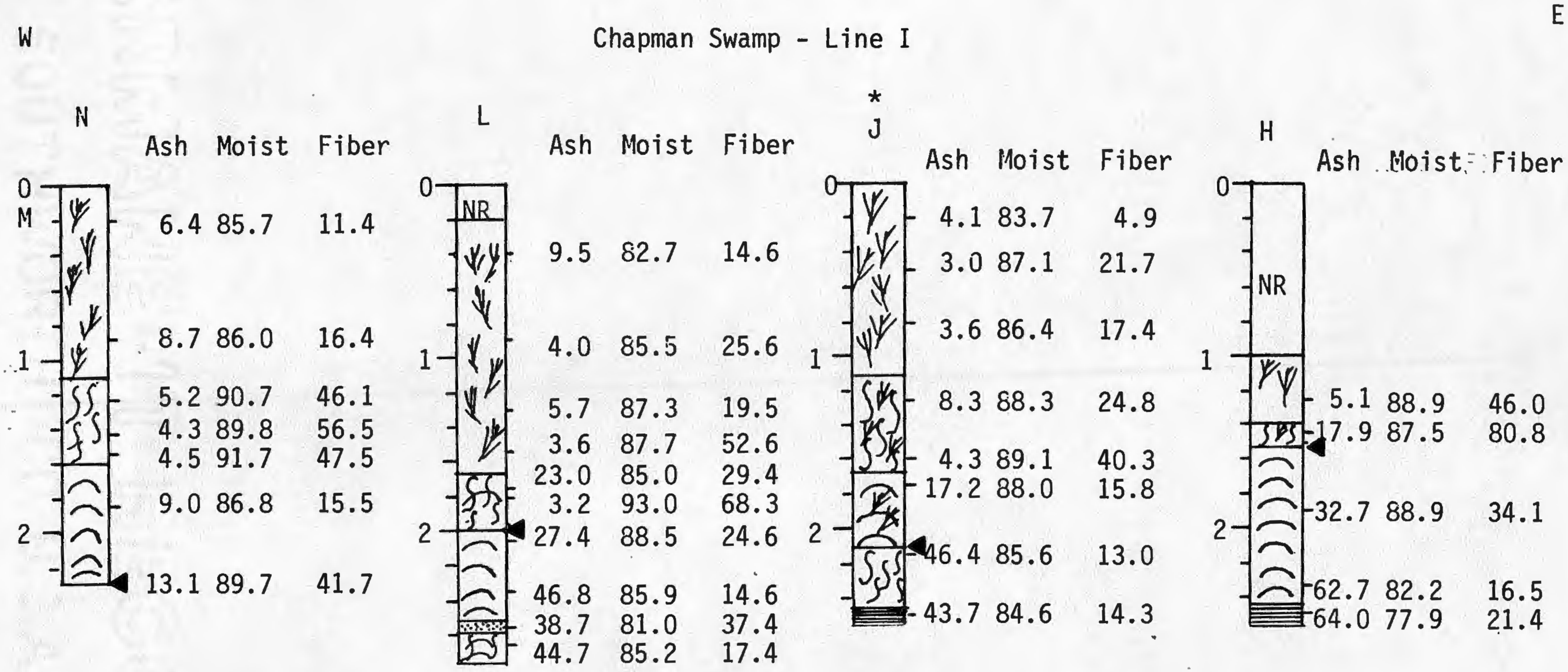
A—— Core designation



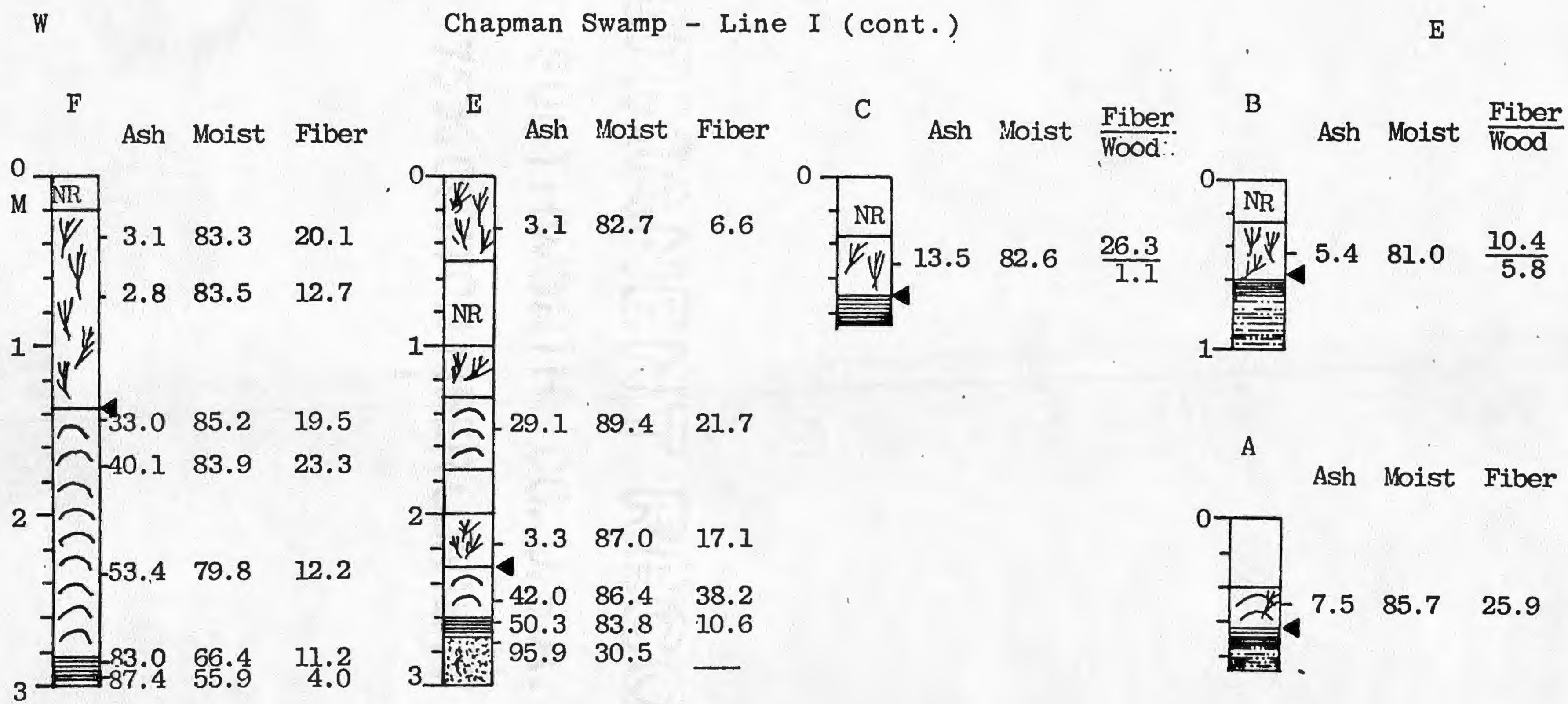
Units of Properties

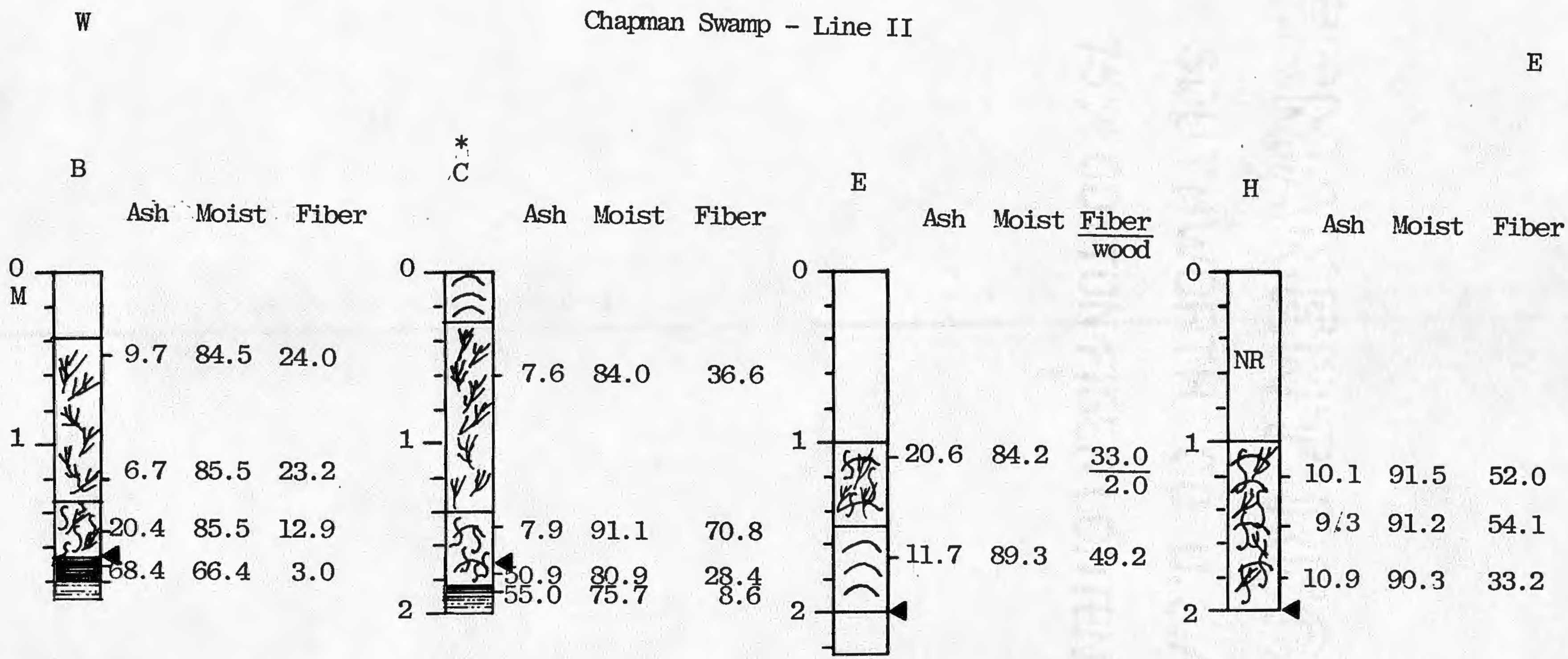
Ash= % (MF)
Moisture= %
Fiber= % 0.25 mm (MF)
Bulk density (ρ_b)= g/cc

Chapman Swamp - Line I



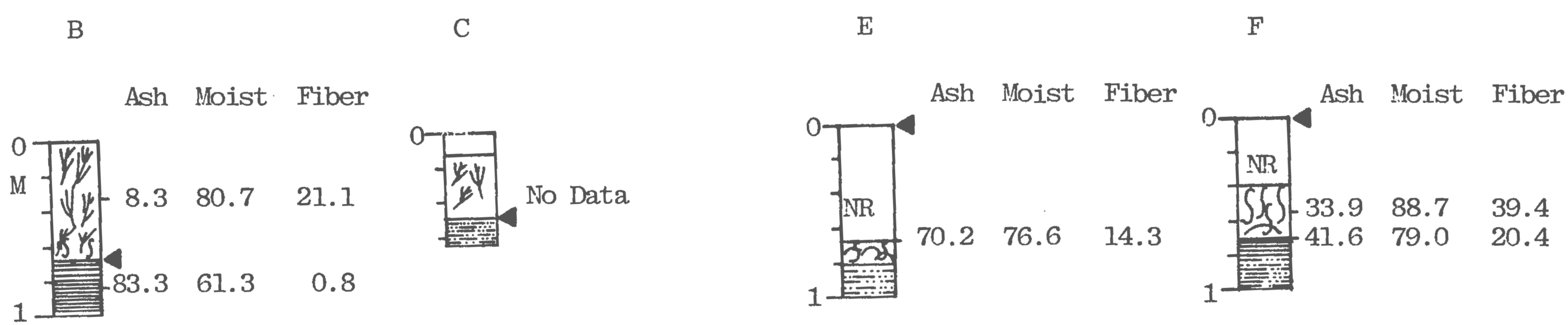
Chapman Swamp - Line I (cont.)

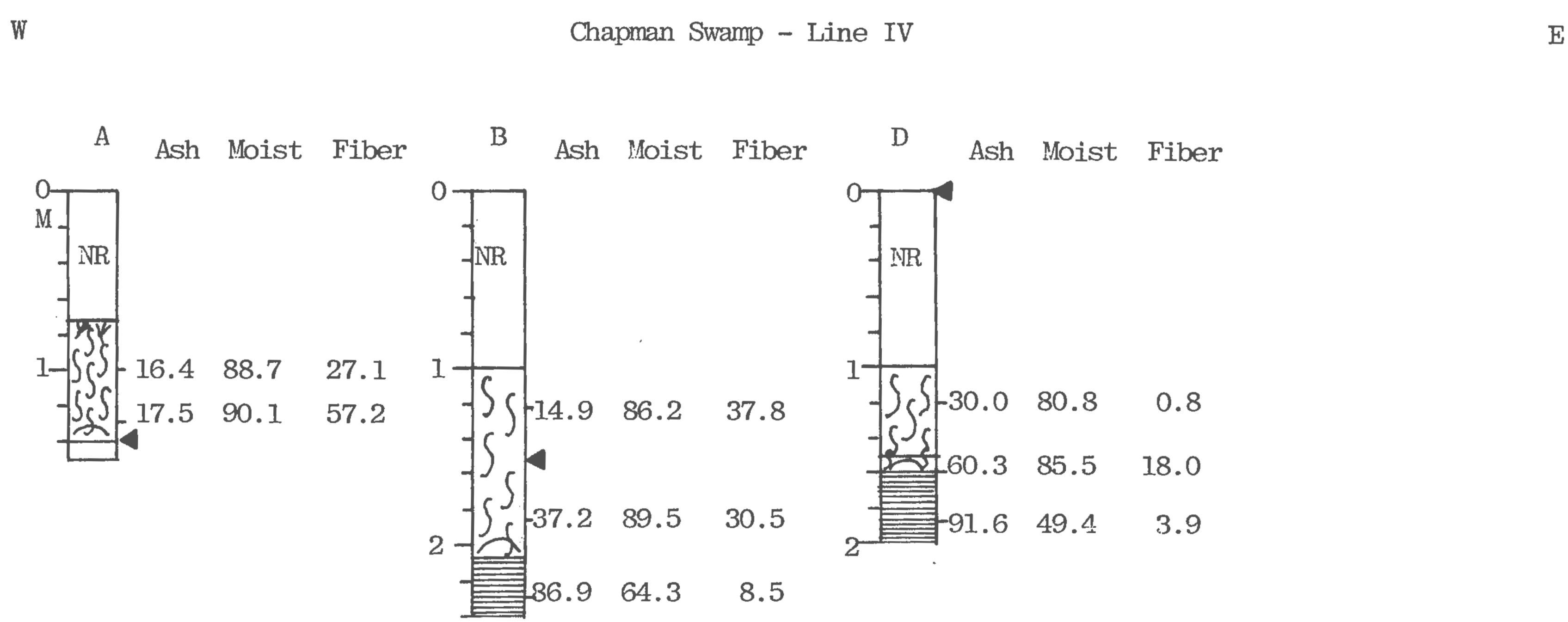


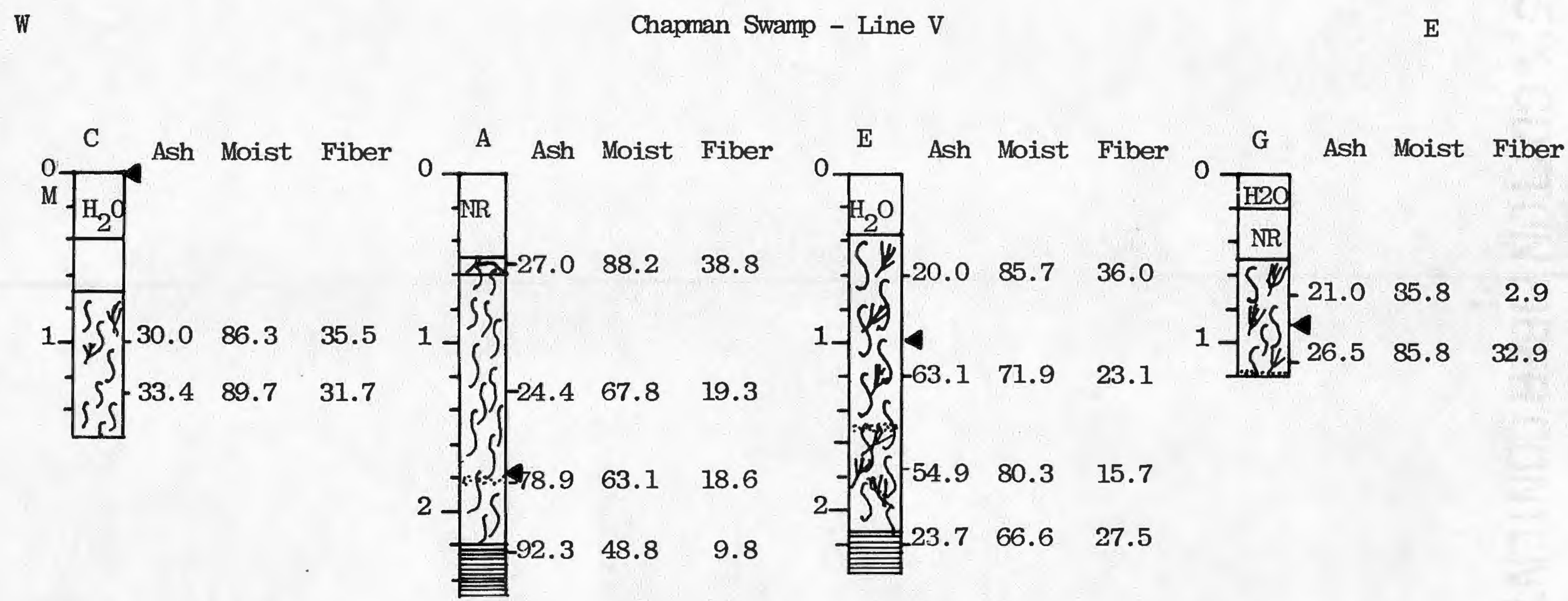


Chapman Swamp - Line II
W
E
B
Ash Moist Fiber
0 M
1
9.7 84.5 24.0
6.7 85.5 23.2
20.4 85.5 12.9
68.4 66.4 3.0
*C
Ash Moist Fiber
0
1
2
7.6 84.0 36.6
7.9 91.1 70.8
50.9 80.9 28.4
55.0 75.7 8.6
E
Ash Moist Fiber/wood
0
1
2
20.6 84.2 33.0/2.0
11.7 89.3 49.2
H
Ash Moist Fiber
0
1
2
NR
10.1 91.5 52.0
9/3 91.2 54.1
10.9 90.3 33.2

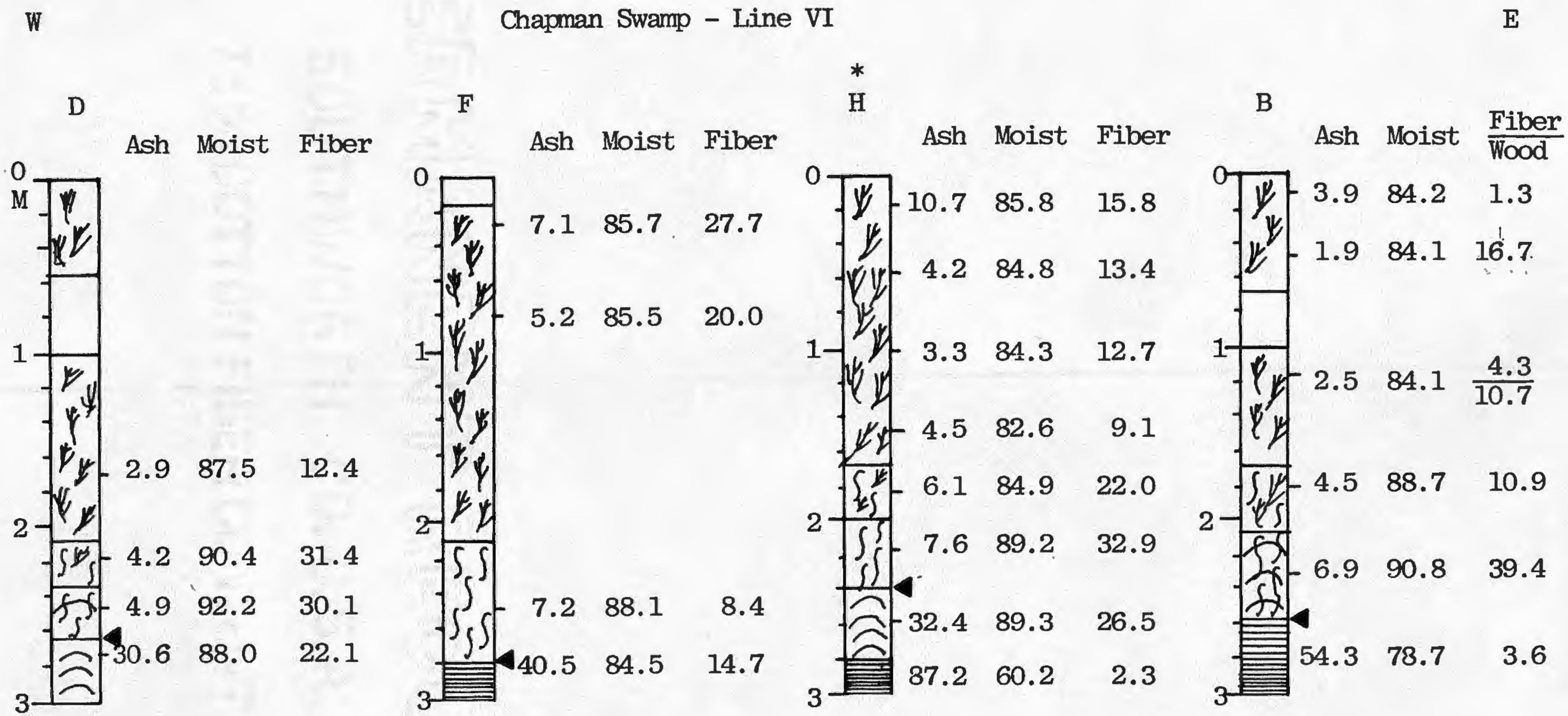
W Chapman Swamp - Line III E



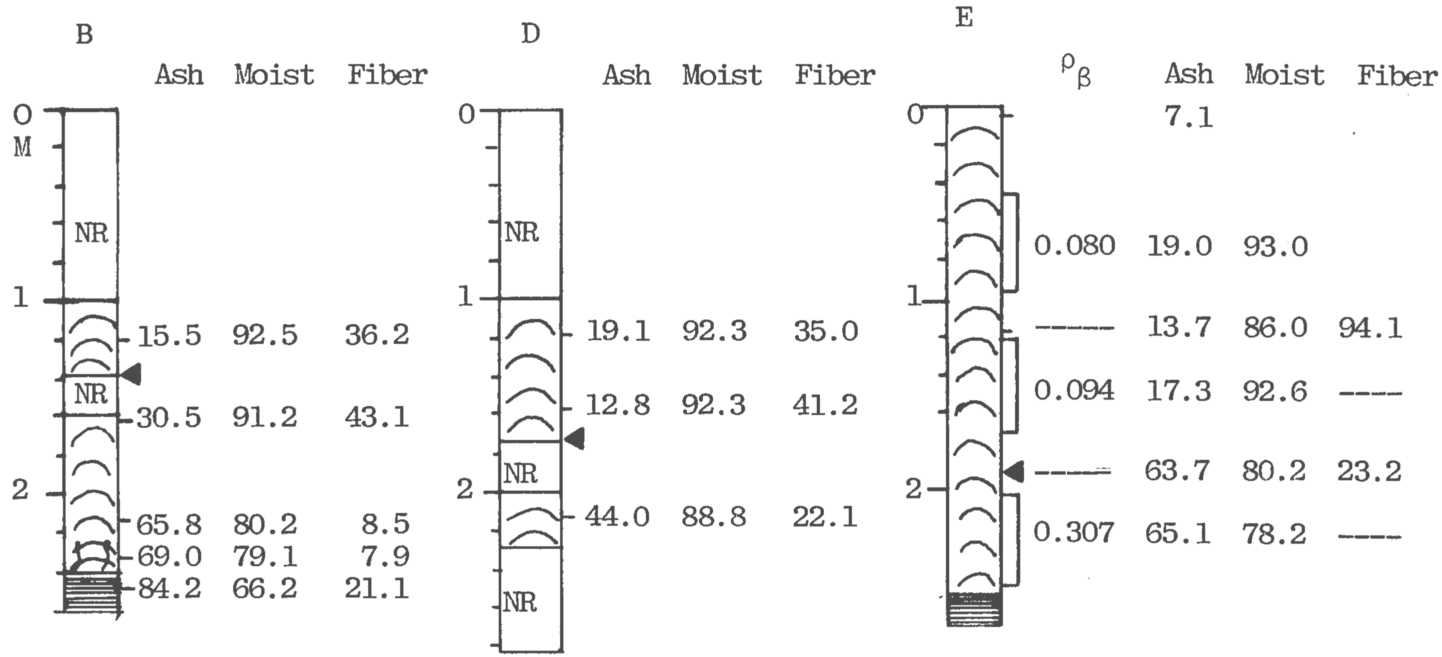

W
Chapman Swamp - Line IV
E
A
Ash Moist Fiber
0
M
NR
1
16.4 88.7 27.1
17.5 90.1 57.2
B
Ash Moist Fiber
0
NR
1
14.9 86.2 37.8
37.2 89.5 30.5
2
86.9 64.3 8.5
D
Ash Moist Fiber
0
NR
1
30.0 80.8 0.8
60.3 85.5 18.0
91.6 49.4 3.9
2

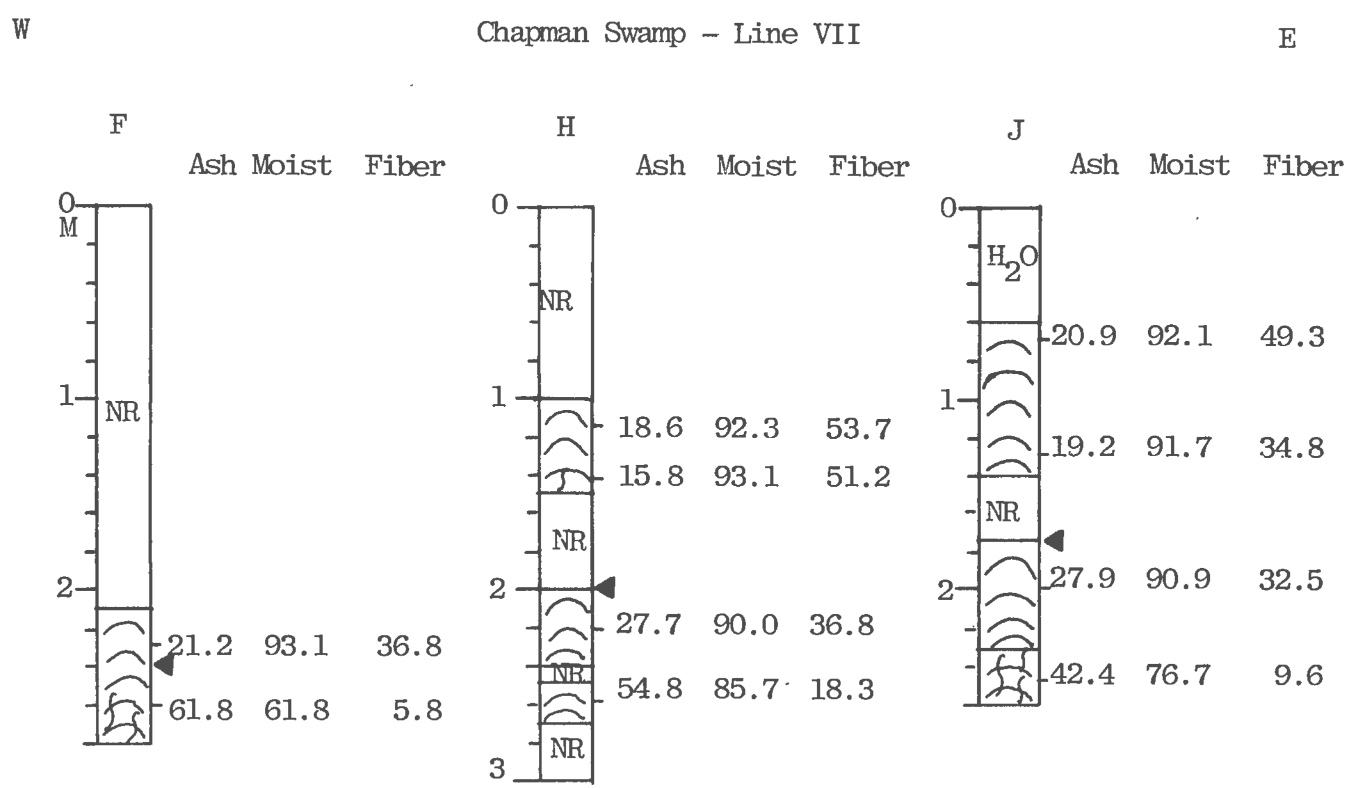

W
Chapman Swamp - Line V
E
C
Ash Moist Fiber
0
M
H_2O
1
30.0 86.3 35.5
33.4 89.7 31.7
A
Ash Moist Fiber
NR
27.0 88.2 38.8
24.4 67.8 19.3
78.9 63.1 18.6
92.3 48.8 9.8
2
E
Ash Moist Fiber
H_2O
20.0 85.7 36.0
63.1 71.9 23.1
54.9 80.3 15.7
23.7 66.6 27.5
G
Ash Moist Fiber
H2O
NR
21.0 35.8 2.9
26.5 85.8 32.9

Chapman Swamp - Line VI

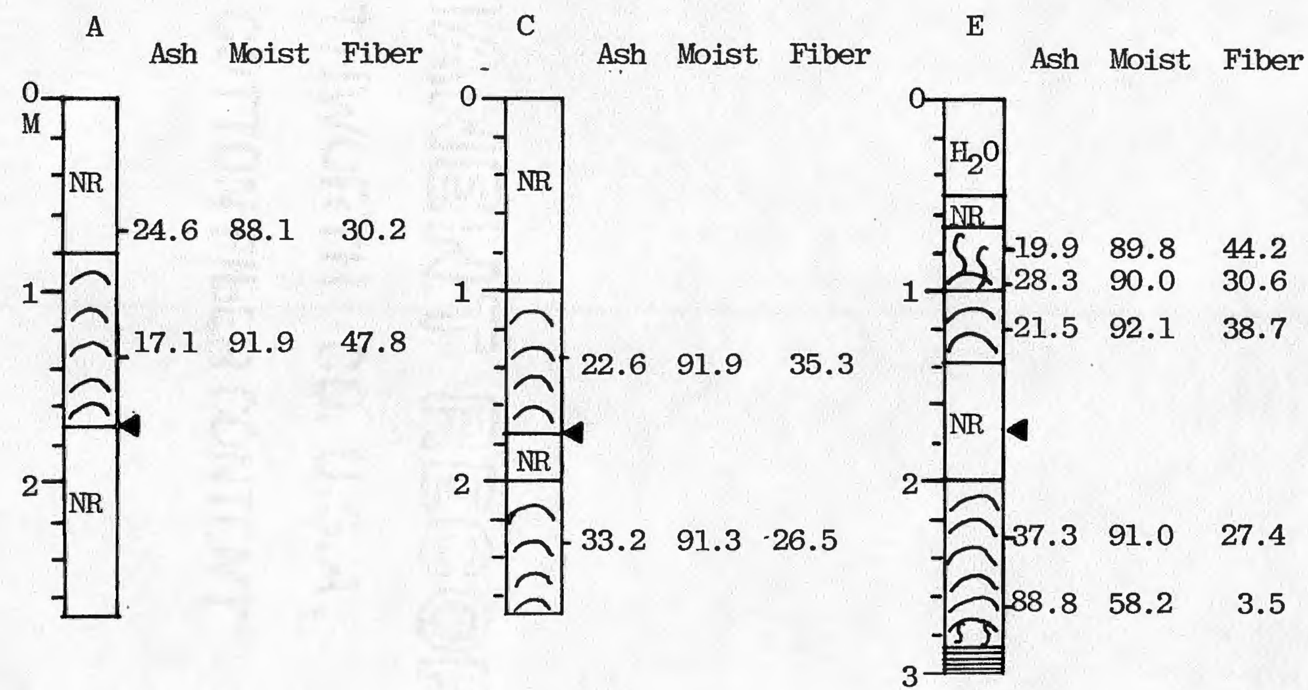


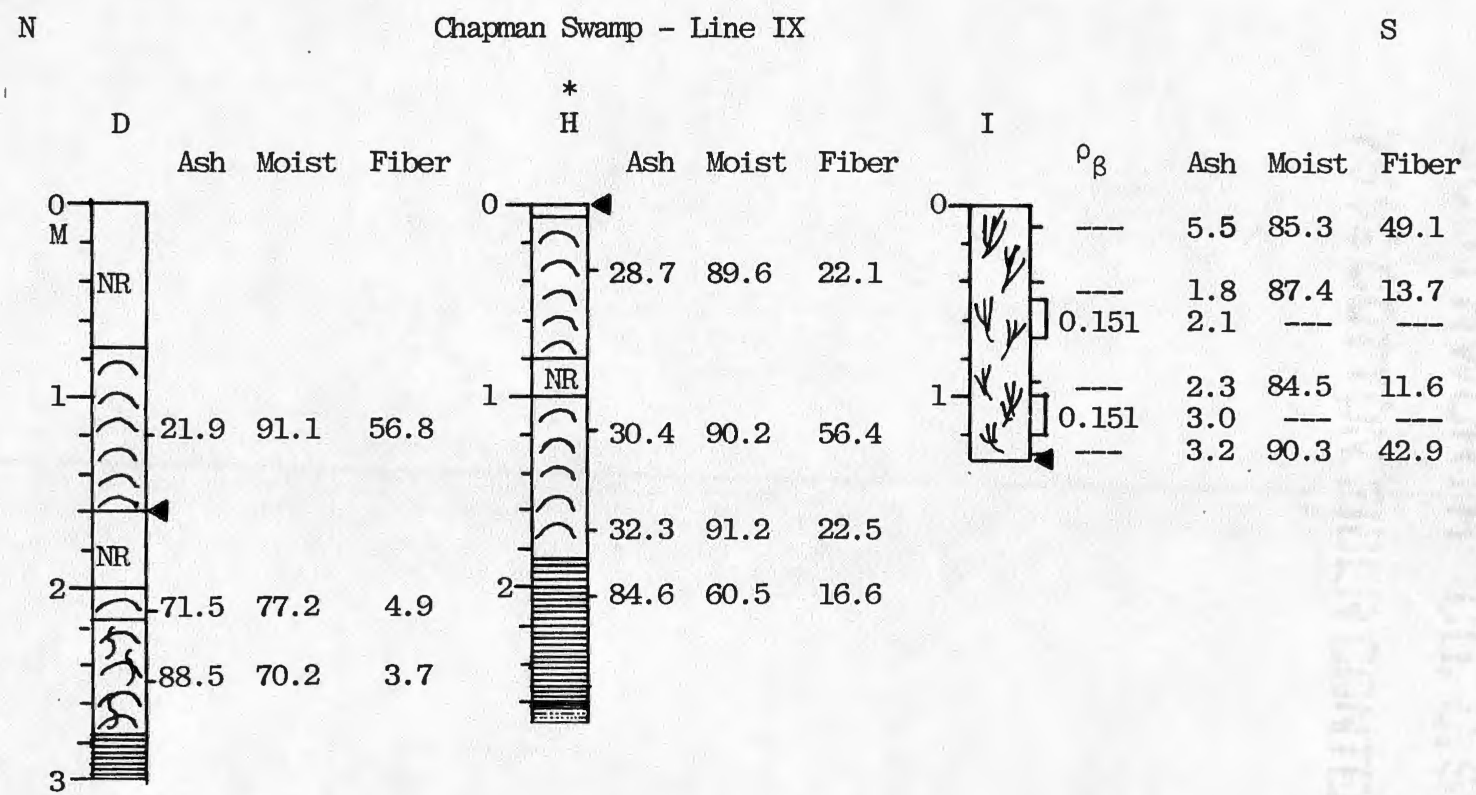
W Chapman Swamp - Line VII E



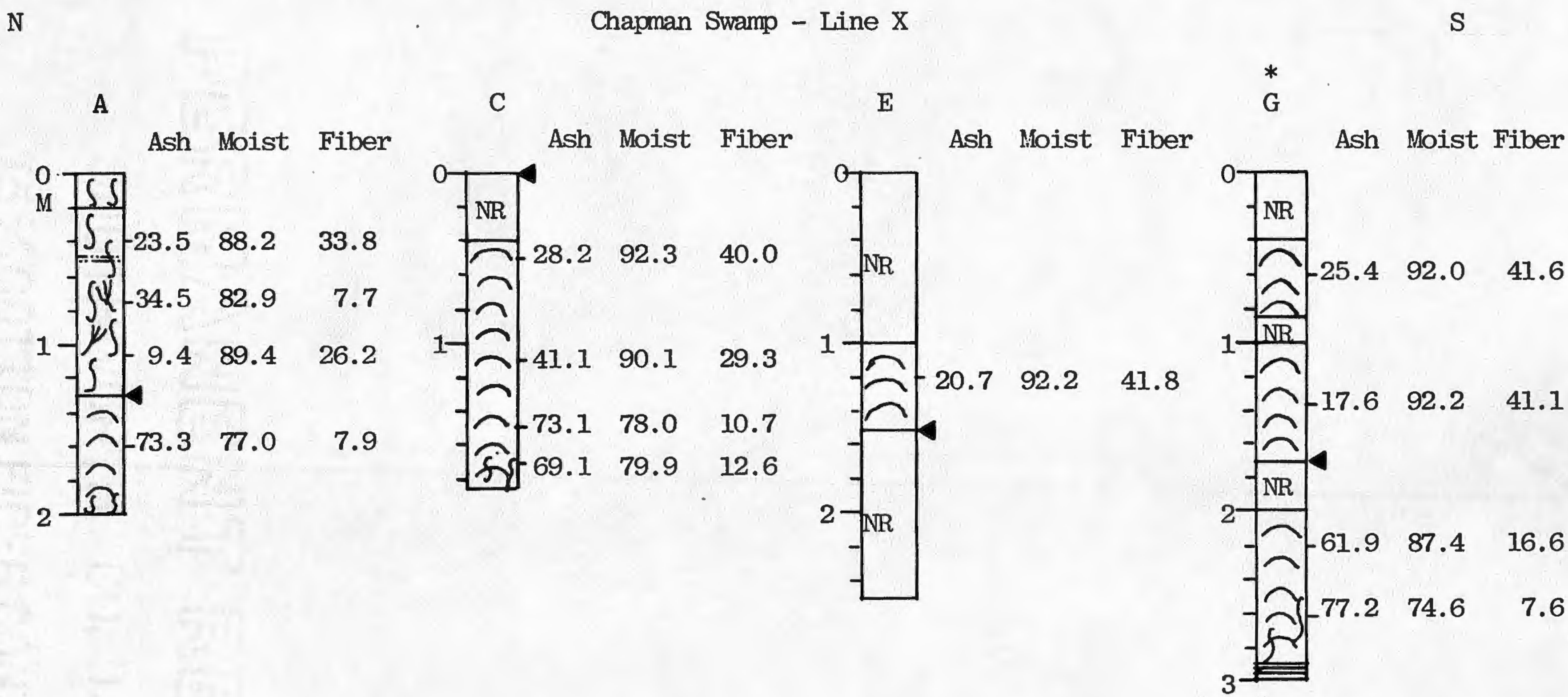

W
Chapman Swamp - Line VII
E
F
Ash Moist Fiber
0
M
1
2
NR
21.2 93.1 36.8
61.8 61.8 5.8
H
Ash Moist Fiber
0
1
2
3
NR
18.6 92.3 53.7
15.8 93.1 51.2
NR
27.7 90.0 36.8
NR
54.8 85.7 18.3
NR
J
Ash Moist Fiber
0
1
2
H_2O
20.9 92.1 49.3
19.2 91.7 34.8
NR
27.9 90.9 32.5
42.4 76.7 9.6

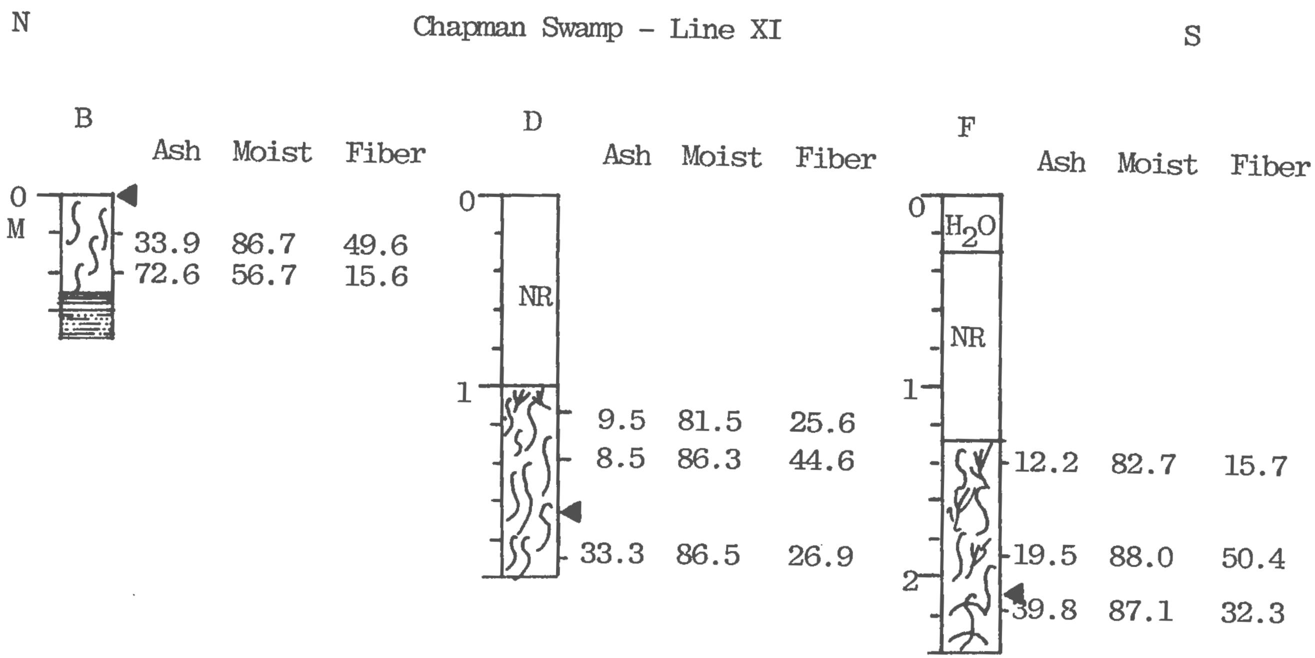
W Chapman Swamp - Line VIII E



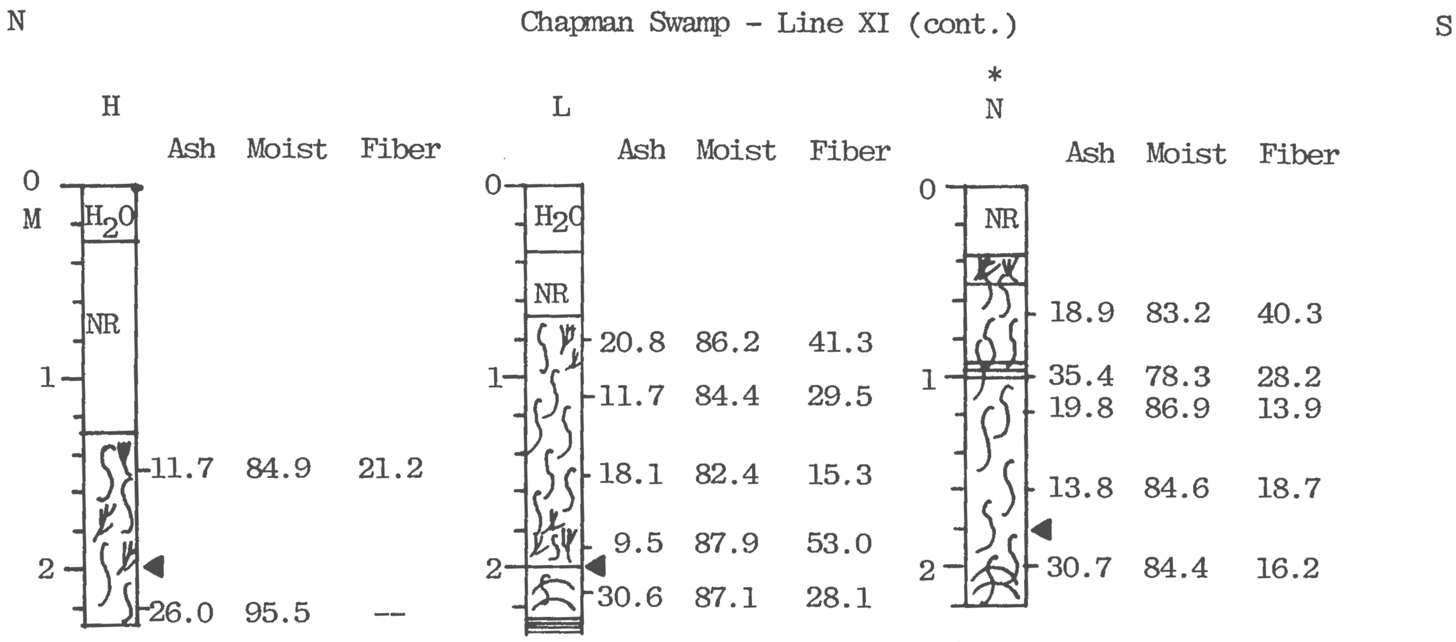

N
Chapman Swamp - Line IX
S
D
Ash Moist Fiber
0
M
NR
1
21.9 91.1 56.8
NR
2
71.5 77.2 4.9
88.5 70.2 3.7
3
*
H
Ash Moist Fiber
0
28.7 89.6 22.1
NR
1
30.4 90.2 56.4
32.3 91.2 22.5
2
84.6 60.5 16.6
I
ρ_β Ash Moist Fiber
0
--- 5.5 85.3 49.1
--- 1.8 87.4 13.7
0.151 2.1 --- ---
1
--- 2.3 84.5 11.6
0.151 3.0 --- ---
--- 3.2 90.3 42.9

Chapman Swamp - Line X




N
Chapman Swamp - Line XI
S
B
Ash Moist Fiber
0
M
33.9 86.7 49.6
72.6 56.7 15.6
D
Ash Moist Fiber
0
NR
1
9.5 81.5 25.6
8.5 86.3 44.6
33.3 86.5 26.9
F
Ash Moist Fiber
0
H2O
NR
1
12.2 82.7 15.7
2
19.5 88.0 50.4
39.8 87.1 32.3

Chapman Swamp - Line XI (cont.)



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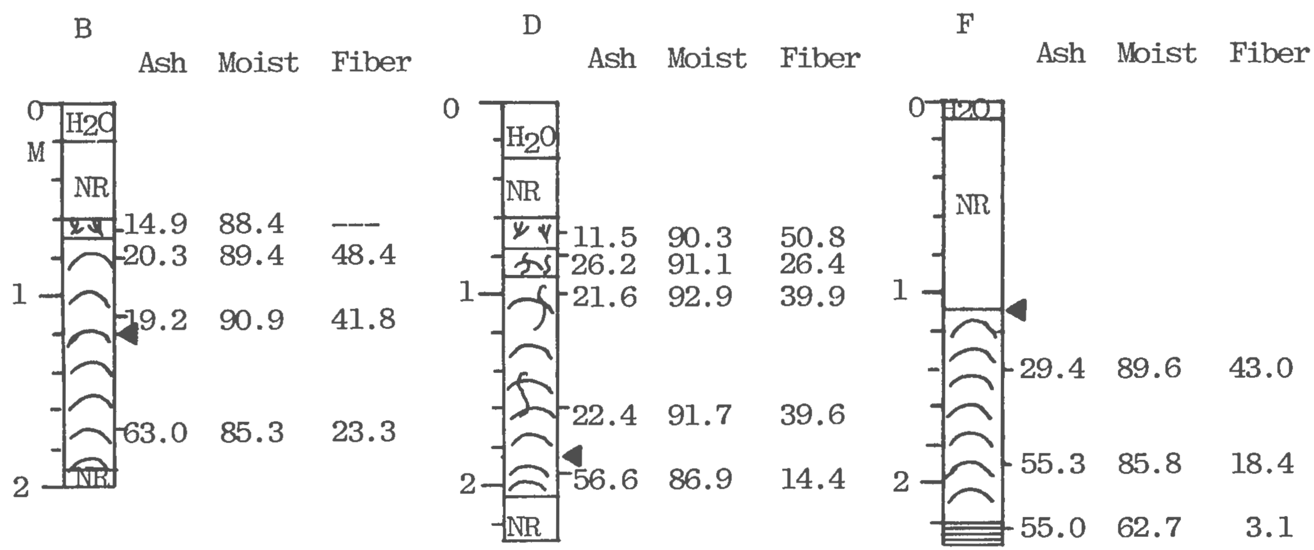
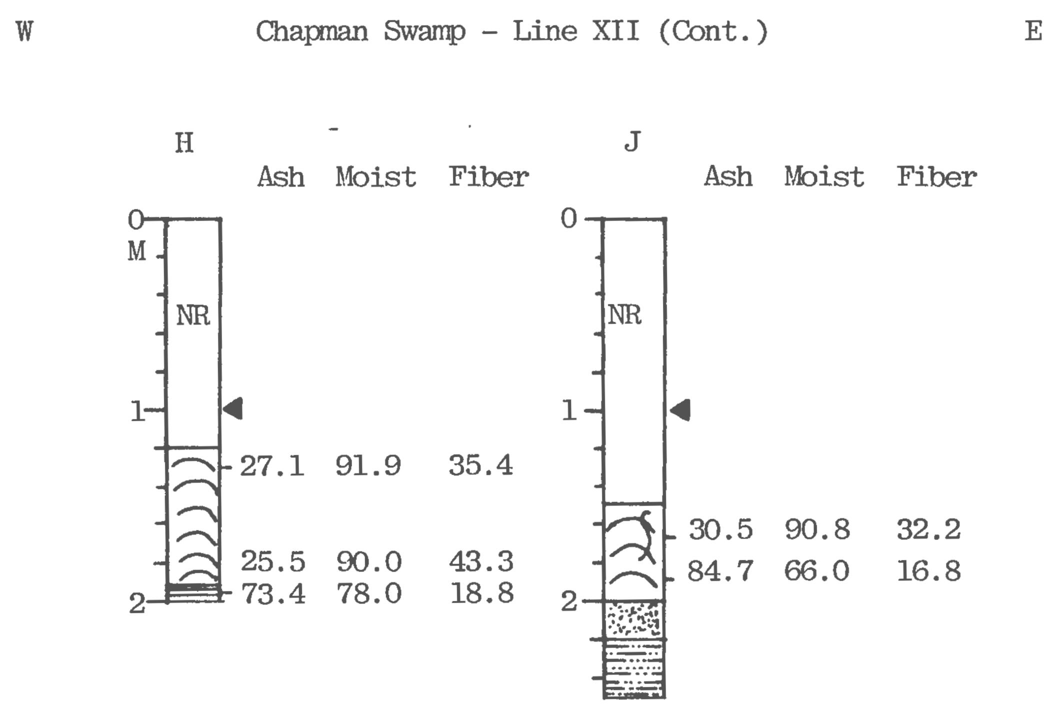
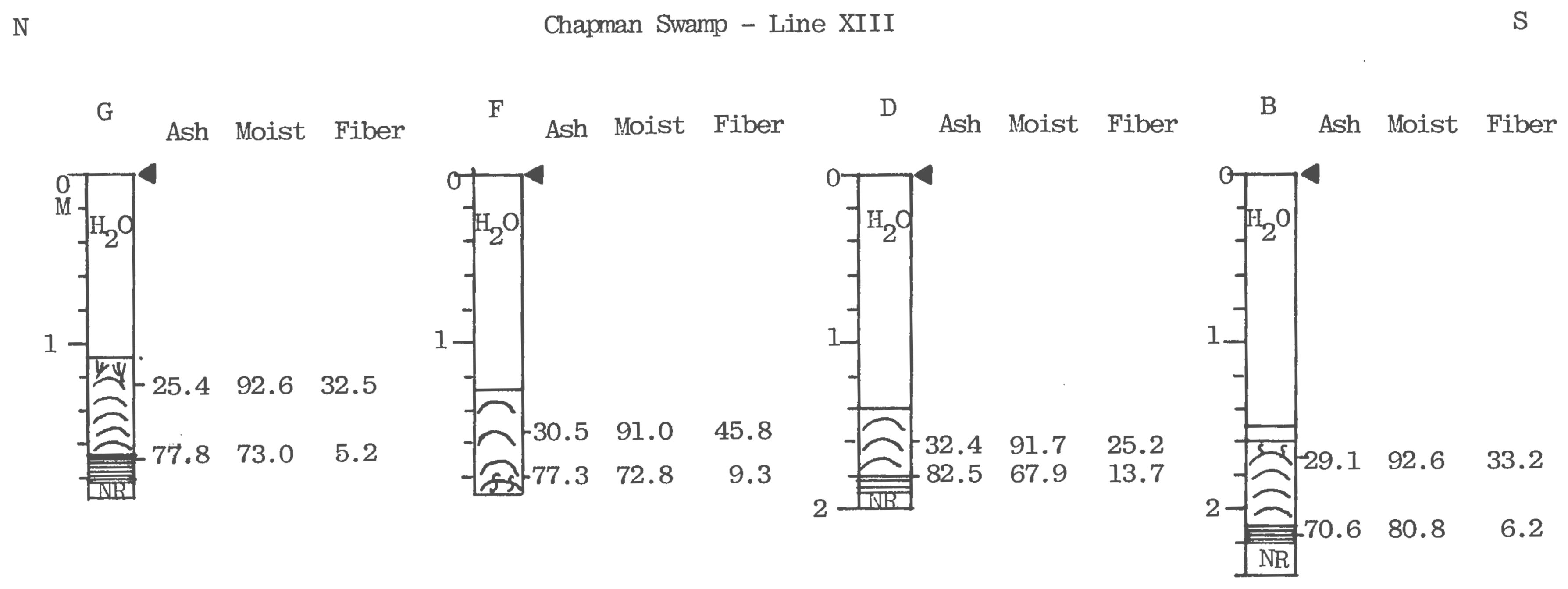
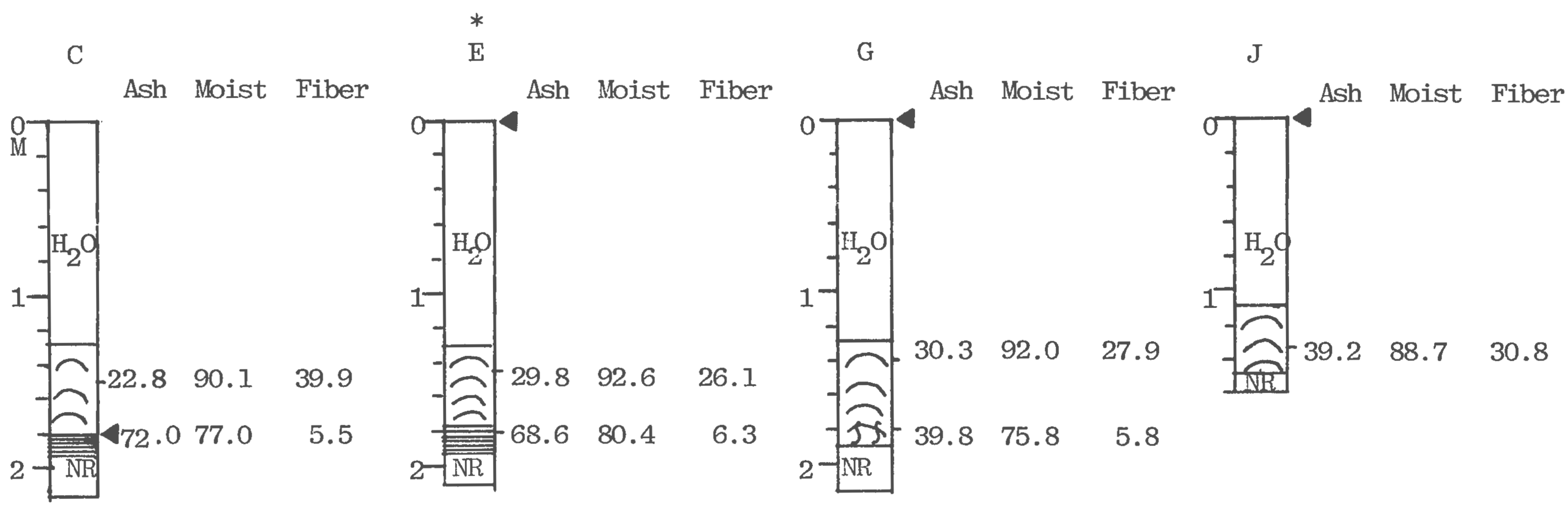



W
Chapman Swamp - Line XII (Cont.)
E
H
Ash Moist Fiber
0
M
NR
1
27.1 91.9 35.4
25.5 90.0 43.3
73.4 78.0 18.8
2
J
Ash Moist Fiber
0
NR
1
30.5 90.8 32.2
84.7 66.0 16.8
2

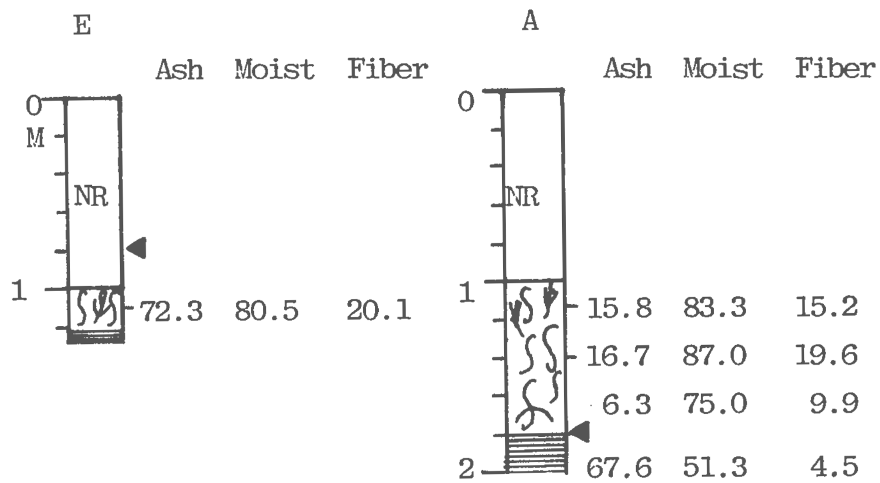
Chapman Swamp - Line XIII



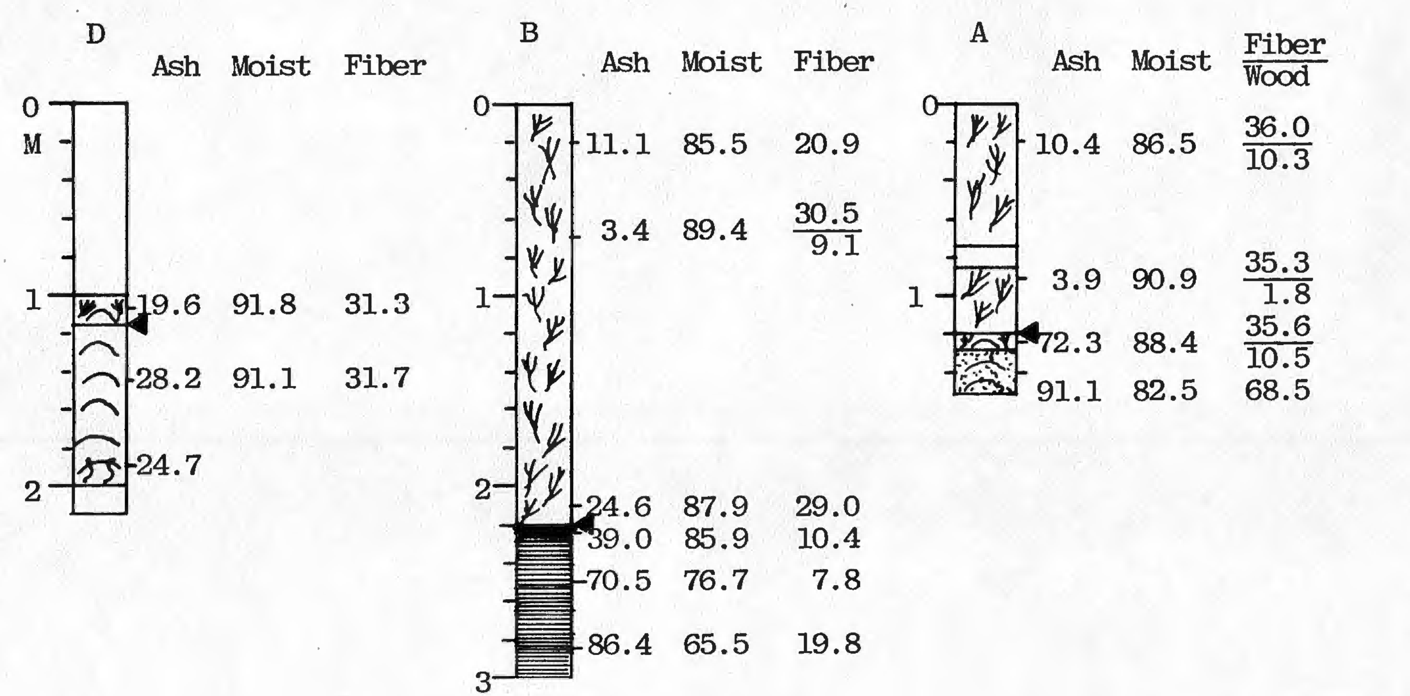
Chapman Swamp - Line XIV



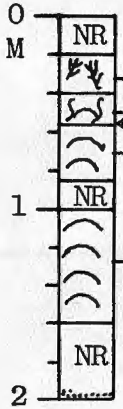
N Chapman Swamp - Line XV S



Chapman Swamp - Line XVI



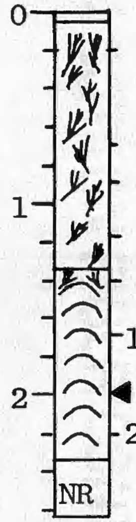
Chapman Swamp - Line XVII-C



Ash	Moist	Fiber
21.6	91.7	42.8
10.1	92.0	36.8
35.1	90.6	26.9
50.9	88.2	10.3

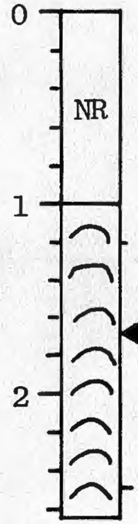
N Chapman Swamp - Line XVIII S

B

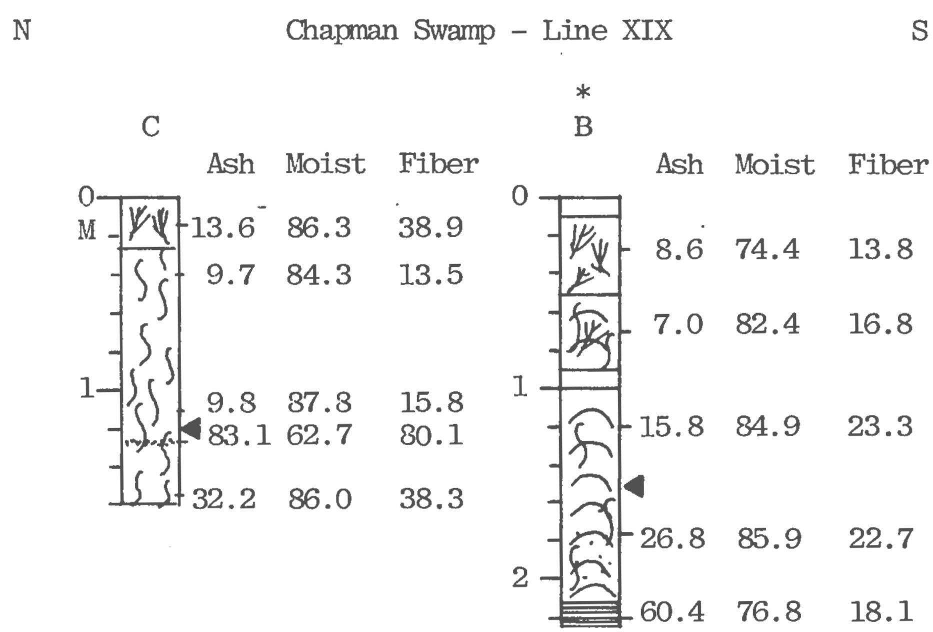


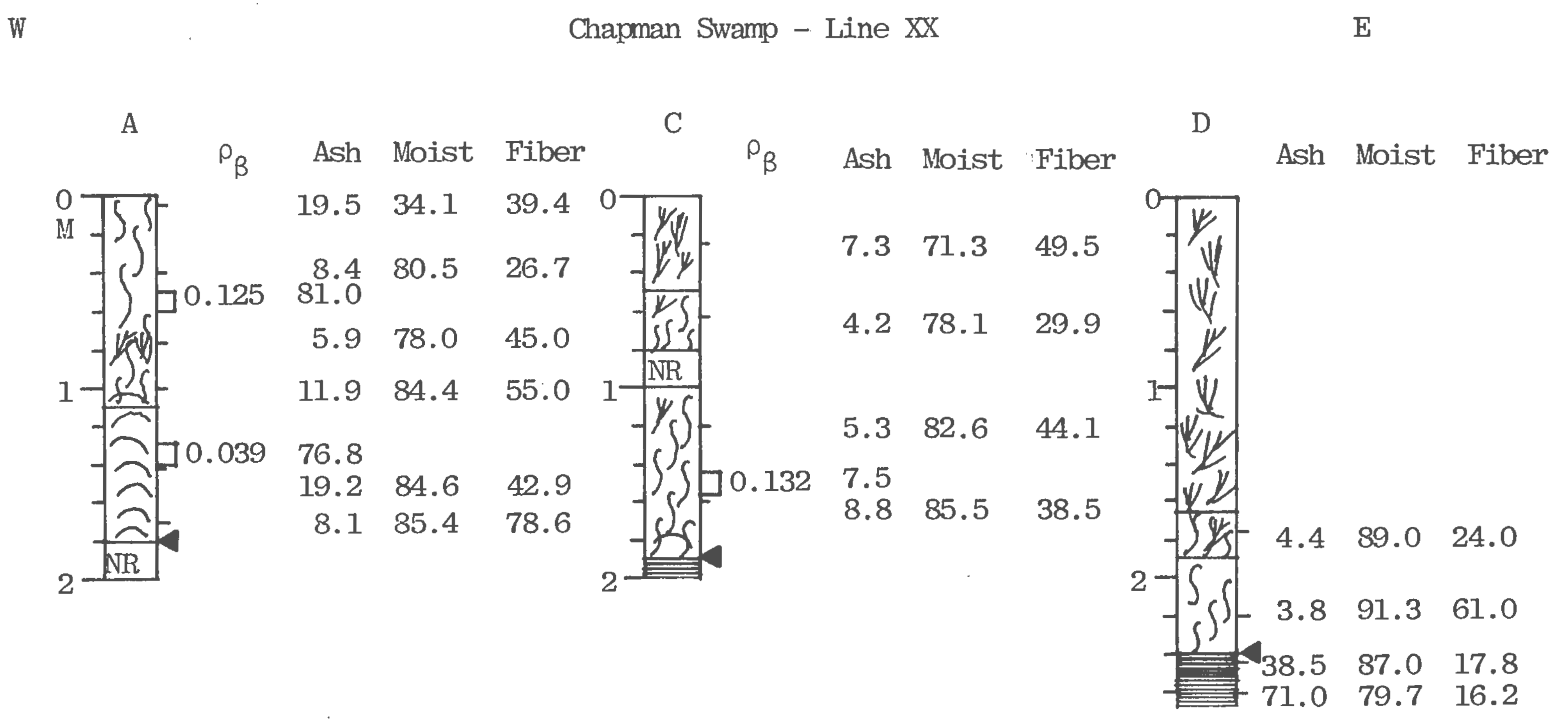
Ash	Moist	Fiber
4.1	86.7	20.4
3.5	90.6	36.1
5.6	90.6	43.0
2.5	91.4	44.0
0.3	91.7	42.1
17.3	90.6	21.1
27.1	91.7	46.6

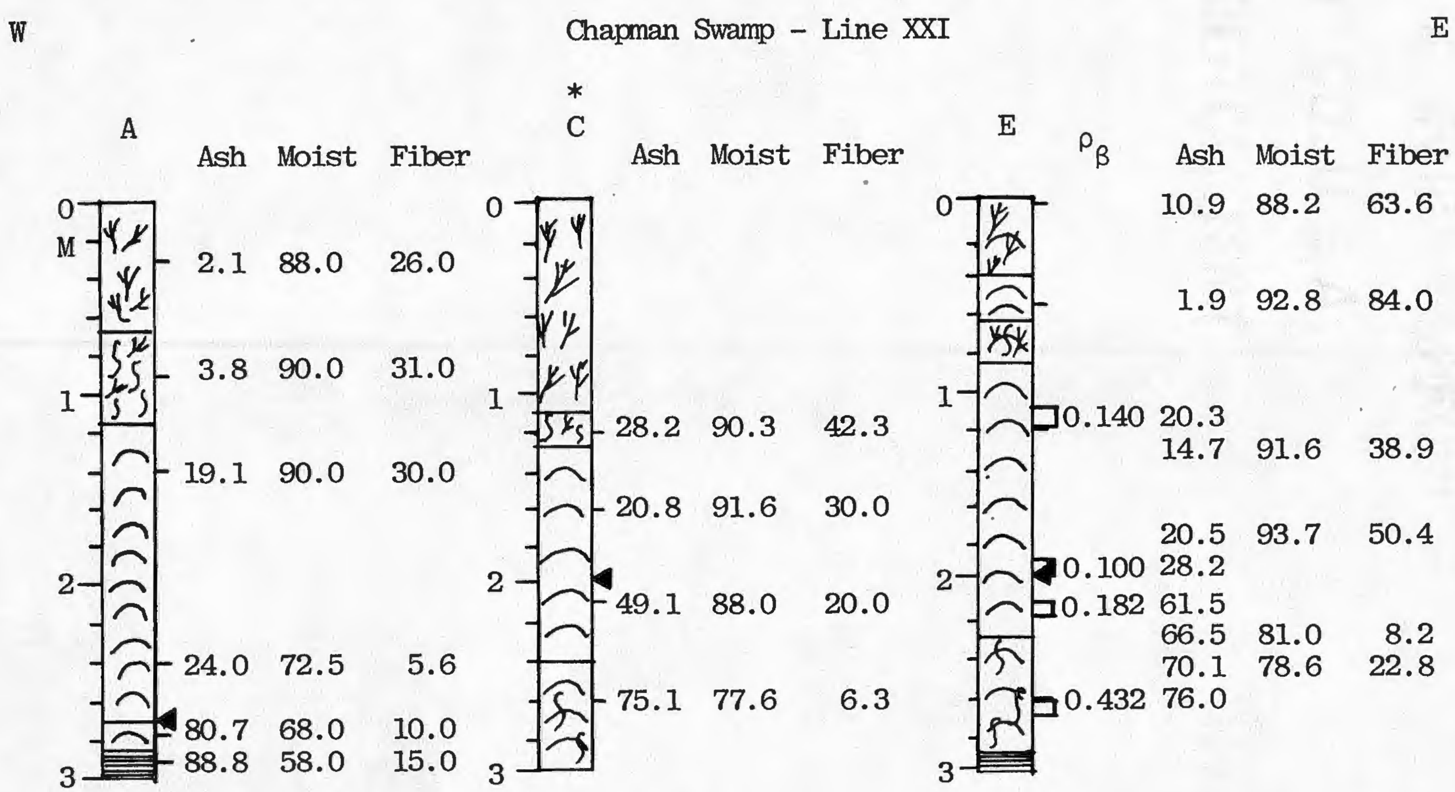
F

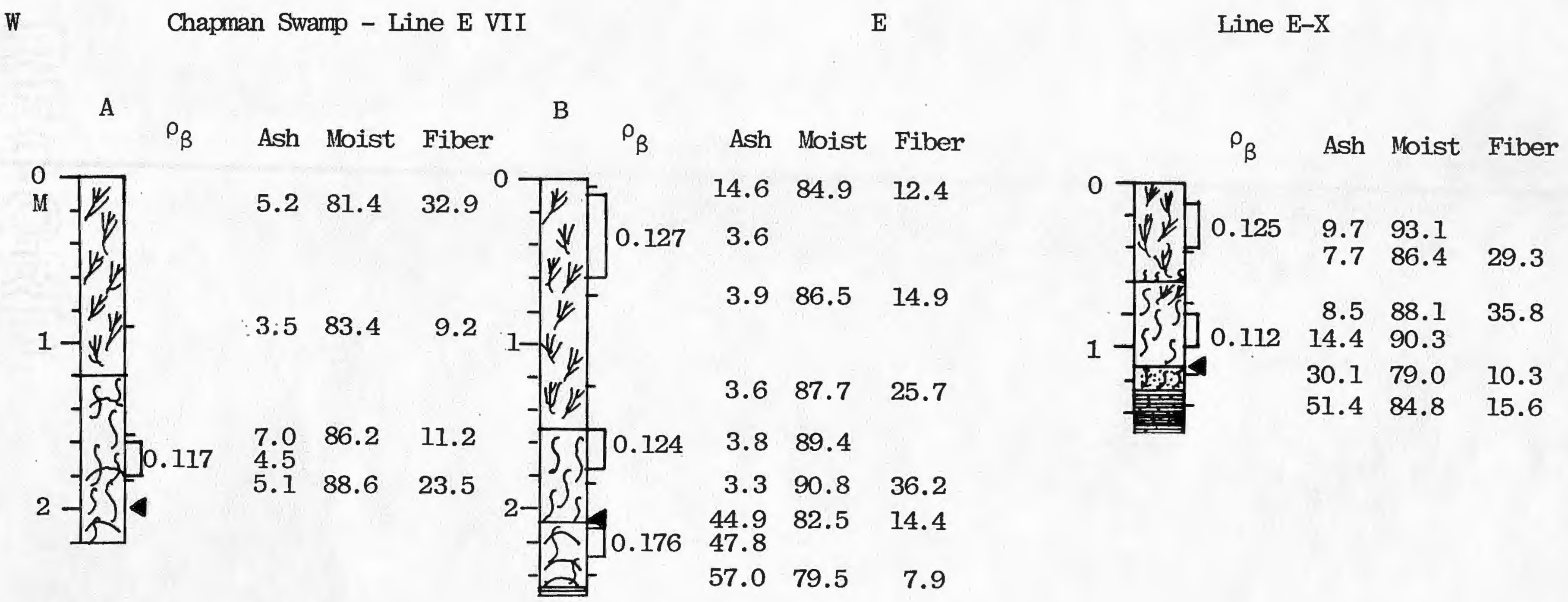


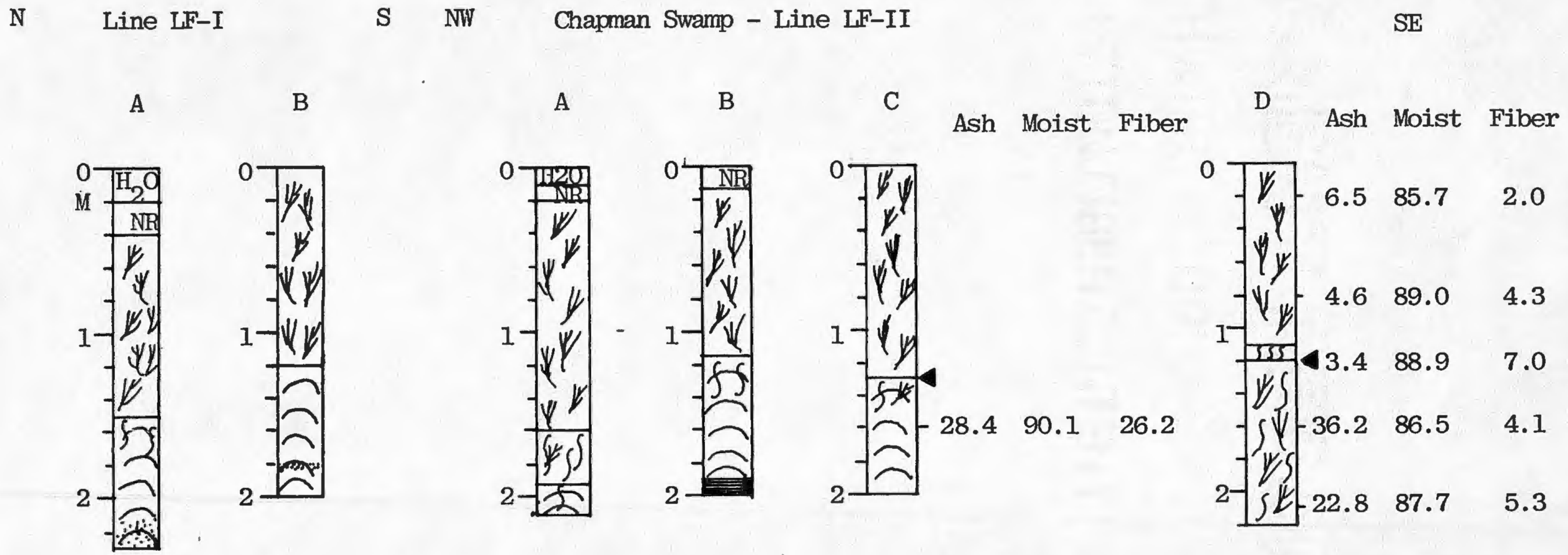
Ash	Moist	Fiber
10.7	90.9	57.3
42.6	89.7	17.5

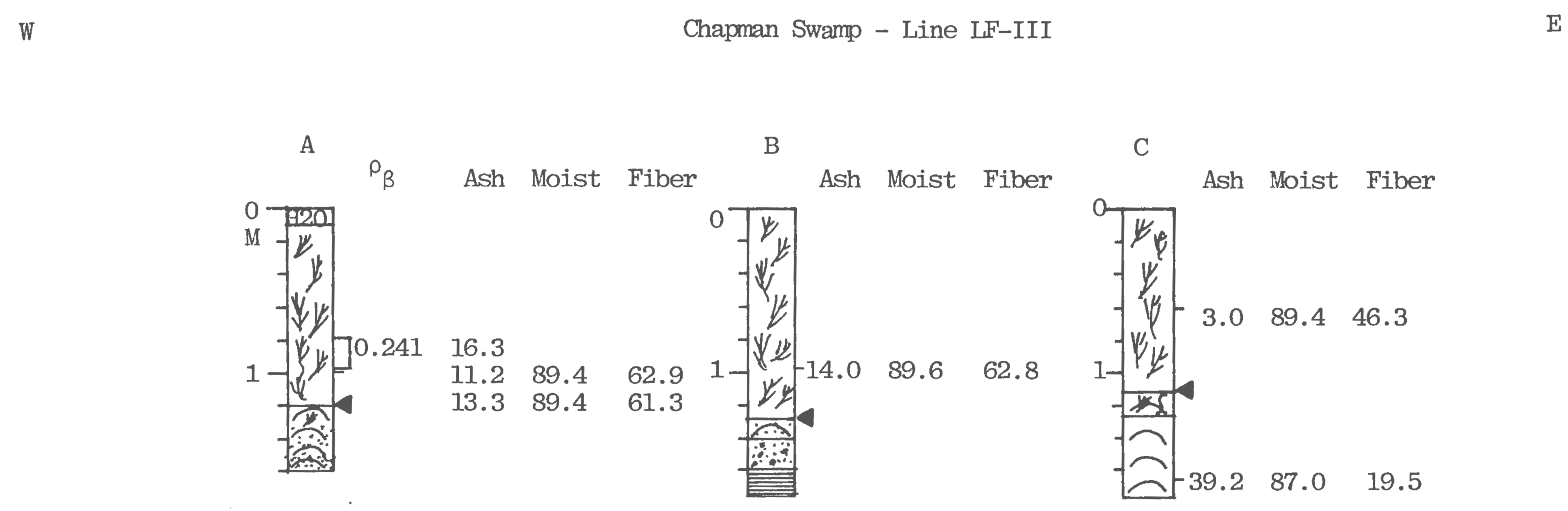

N
Chapman Swamp - Line XIX
S
C
Ash Moist Fiber
0
M
1
13.6 86.3 38.9
9.7 84.3 13.5
9.8 87.8 15.8
83.1 62.7 80.1
32.2 86.0 38.3
*
B
Ash Moist Fiber
0
1
2
8.6 74.4 13.8
7.0 82.4 16.8
15.8 84.9 23.3
26.8 85.9 22.7
60.4 76.8 18.1

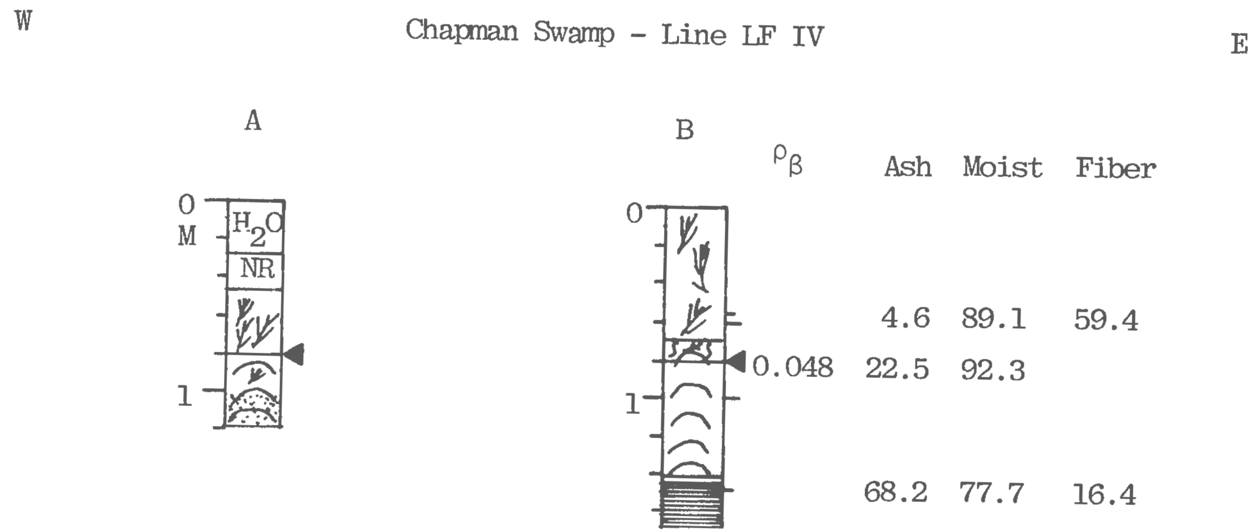

W
Chapman Swamp - Line XX
E
A
ρ_β
Ash Moist Fiber
0
M
1
2
NR
0.125
0.039
19.5 34.1 39.4
8.4 80.5 26.7
81.0
5.9 78.0 45.0
11.9 84.4 55.0
76.8
19.2 84.6 42.9
8.1 85.4 78.6
C
ρ_β
Ash Moist Fiber
0
1
2
NR
0.132
7.3 71.3 49.5
4.2 78.1 29.9
5.3 82.6 44.1
7.5
8.8 85.5 38.5
D
Ash Moist Fiber
0
1
2
4.4 89.0 24.0
3.8 91.3 61.0
38.5 87.0 17.8
71.0 79.7 16.2


W
Chapman Swamp - Line XXI
E
A
Ash Moist Fiber
0
M
1
2
3
2.1 88.0 26.0
3.8 90.0 31.0
19.1 90.0 30.0
24.0 72.5 5.6
80.7 68.0 10.0
88.8 58.0 15.0
*
C
Ash Moist Fiber
28.2 90.3 42.3
20.8 91.6 30.0
49.1 88.0 20.0
75.1 77.6 6.3
E
ρ_β
Ash Moist Fiber
10.9 88.2 63.6
1.9 92.8 84.0
0.140 20.3
14.7 91.6 38.9
20.5 93.7 50.4
0.100 28.2
0.182 61.5
66.5 81.0 8.2
70.1 78.6 22.8
0.432 76.0


W
Chapman Swamp - Line E VII
E
Line E-X
A
B
ρ_β
Ash
Moist
Fiber
0
M
1
2
5.2 81.4 32.9
3.5 83.4 9.2
7.0 86.2 11.2
4.5
5.1 88.6 23.5
0.117
0.127
0.124
0.176
14.6 84.9 12.4
3.6
3.9 86.5 14.9
3.6 87.7 25.7
3.8 89.4
3.3 90.8 36.2
44.9 82.5 14.4
47.8
57.0 79.5 7.9
0.125
0.112
9.7 93.1
7.7 86.4 29.3
8.5 88.1 35.8
14.4 90.3
30.1 79.0 10.3
51.4 84.8 15.6


N
Line LF-I
S
NW
Chapman Swamp - Line LF-II
SE
A
B
A
B
C
D
Ash Moist Fiber
28.4 90.1 26.2
Ash Moist Fiber
6.5 85.7 2.0
4.6 89.0 4.3
3.4 88.9 7.0
36.2 86.5 4.1
22.8 87.7 5.3
M
H_2O
NR
H2O
NR
NR
0
1
2


W
Chapman Swamp - Line LF-III
E
A
ρ_β
Ash Moist Fiber
0
M
H2O
1
0.241
16.3
11.2 89.4 62.9
13.3 89.4 61.3
B
Ash Moist Fiber
0
1
14.0 89.6 62.8
C
Ash Moist Fiber
0
1
3.0 89.4 46.3
39.2 87.0 19.5


W
Chapman Swamp - Line LF IV
E
A
0
M
H_2O
NR
1
B
ρ_β
Ash
Moist
Fiber
0
4.6
89.1
59.4
0.048
22.5
92.3
1
68.2
77.7
16.4

APPENDIX 3:

Fuel Analyses

			PROXIMATE ANALYSIS				ULTIMATE ANALYSIS MOISTURE FREE						
Core	Peat Type	Depth (m)	%Total Moisture	%Volatile Matter	%Fixed Carbon	%Ash	%Carbon	%Hydrogen	%Nitrogen	%Sulfur	%Oxygen	Calorific Value (BTU/lb) Moist. free	35% moist
IJ-2	Reed-Sedge	1.0-2.0	86.5	56.9	30.2	12.9	53.34	4.55	1.43	0.46	27.32	9175	5964
IJ-3	Reed-Sedge	2.0-3.0	85.2	41.7	20.5	37.8	36.64	3.19	1.57	0.48	20.32	6444	4189
IIC-1	Wood	0.3-1.0	85.5	62.7	30.6	6.7	56.95	4.91	1.85	0.48	29.11	9726	6322
IIC-2	Reed-Sedge	1.4-1.8	84.9	46.1	22.9	31.0	40.73	3.69	1.48	0.70	22.4	7207	4685
VI H-1	Wood	0 -1.0	85.5	62.7	31.0	6.3	56.25	4.97	1.56	0.56	30.36	9953	6469
VI H-2	Reed-Sedge	2.0-2.4	89.8	60.2	33.0	6.8	56.36	5.08	2.20	0.57	28.99	9740	6331
VI H-3	Moss	2.4-2.8	88.2	41.0	18.1	40.9	35.55	3.24	1.76	0.48	18.07	6169	4010
VI H-4	Org. Mud	2.8-3.0	63.7	11.5	1.9	86.6	7.08	0.79	0.44	0.15	4.94	1201	781
VI H-5	Wood	1.0-1.7	83.9	64.0	32.8	3.2	61.78	5.21	1.13	0.33	28.35	10803	7022
IX H-1	Moss	0.05-0.5	89.7	50.1	20.3	29.6	40.38	3.99	2.55	0.50	22.68	7030	4570
IX H-2	Moss	1.5-1.85	88.4	37.9	15.8	46.3	30.61	2.94	1.81	.44	17.9	5441	3537
XG-1	Moss	.04-.85	90.1	50.8	21.2	28.0	40.84	4.04	2.45	0.59	24.08	7149	4647
XG-2	Moss	1.2-1.6	92.0	56.7	25.8	17.5	48.72	4.68	2.81	0.47	25.82	8561	5565
XG-3	Moss	2.0-2.4	83.0	28.8	11.9	59.3	23.44	2.29	1.59	0.68	12.70	4018	2612
XG-4	Moss	2.4-2.9	71.6	14.2	5.4	80.4	11.08	0.95	0.66	0.45	6.46	1823	1185
XI N-1	Reed-Sedge	0.5-0.85	88.4	61.7	33.1	5.2	56.17	4.75	1.26	0.38	32.24	9651	6273
XI N-2	Reed-Sedge	0.85-1.1	99.6	35.9	13.9	50.2	30.26	2.67	1.03	0.58	15.26	5443	3538
XI N-3	Reed-Sedge	1.5-1.8	87.8	50.9	28.1	21.0	50.33	4.03	2.37	0.99	21.28	8658	5628
XI N-4	Org. Mud	1.8-2.2	79.2	27.3	9.5	63.2	22.10	2.14	1.09	0.52	10.95	3966	2592
XIV E-1	Moss	0 -0.7	90.0	39.3	16.5	44.2	33.13	3.33	1.91	0.56	16.87	5824	3786
XIX B-1	Wood	0.1-0.5	85.4	61.3	27.3	11.4	55.39	4.90	3.24	0.57	24.50	9535	4248
XIX B-2	Reed-Sedge	0.5-0.9	86.0	61.9	31.7	6.4	60.42	5.43	1.16	0.53	26.06	10520	6838
XIX B-3	Moss	1.0-1.5	90.6	56.1	28.5	15.4	50.87	4.65	4.27	0.55	24.26	8852	5754
XIX B-4	Sandy Moss	1.5-2.0	80.9	29.1	12.8	58.1	25.19	2.14	1.09	0.50	12.98	4383	2849
XXI C-1	Wood	0 -1.0	88.6	64.3	32.1	3.6	57.11	5.34	1.43	0.43	32.09	9681	6293
XXI C-2	Moss	1.3-2.4	91.1	53.5	25.6	20.9	46.93	4.42	5.41	0.47	21.87	8164	5307
XXI C-3	Moss	2.4-2.9	76.4	20.6	7.5	71.9	15.77	1.37	0.84	0.60	9.52	2740	1781
Mean			85.63	46.19	21.78	32.03	40.87	3.69	1.87	0.52	21.01	7106	4619
Maximum			99.60	64.30	33.10	86.6	61.78	5.43	5.41	0.99	32.24	10803	7022
Minimum			63.70	11.50	1.90	3.2	7.08	0.79	0.44	0.15	4.94	1201	781